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Modern Interior Lighting

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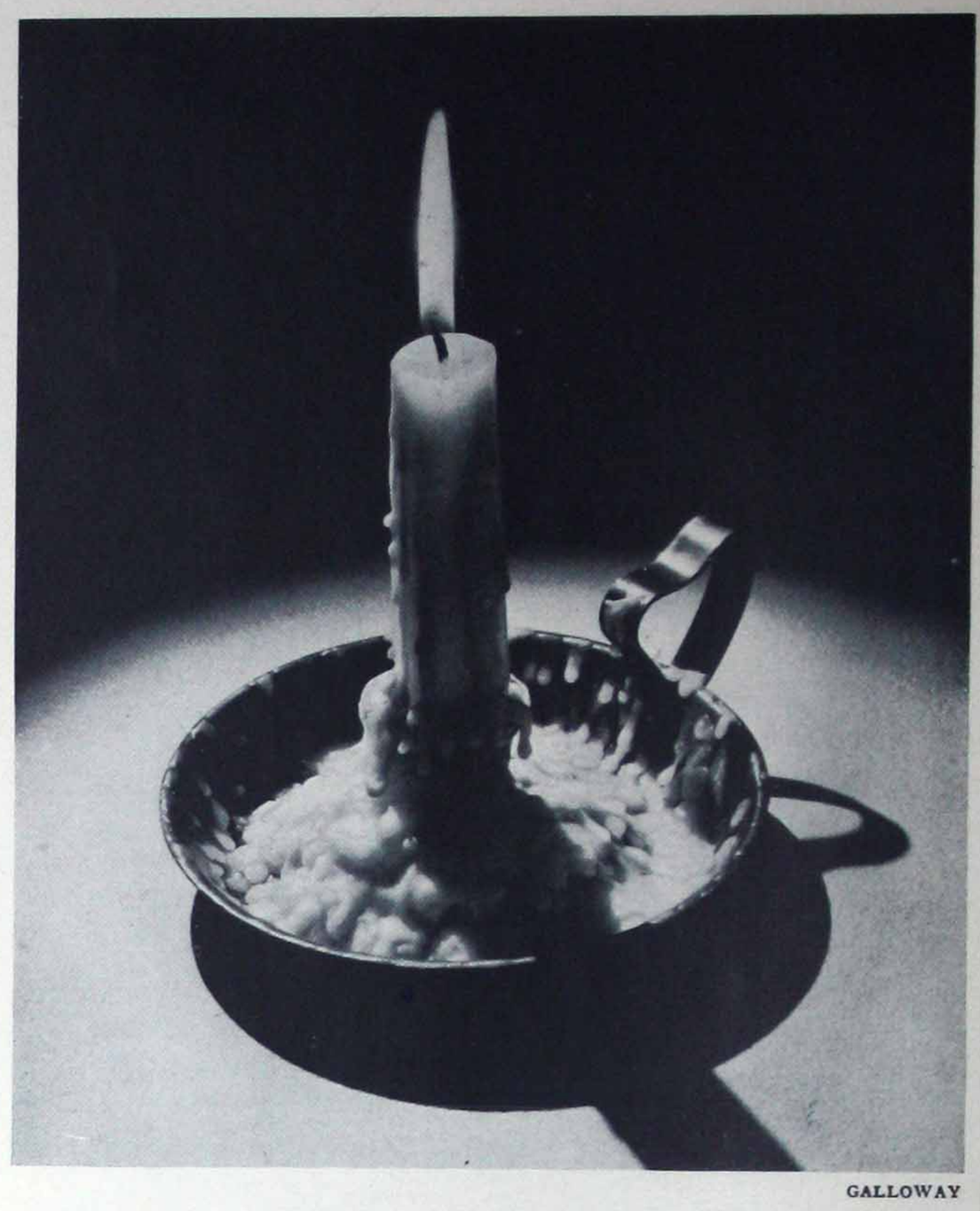
INCANDESCENT LAMP DEPARTMENT

GENERAL ELECTRIC COMPANY

A.I.A. File No. 31-F

Blueprint

Tradition of the Flame



GALLOWAY

BEFORE the advent of the incandescent lamp all artificial light sources employed flames. They had to be supported away from walls, ceilings and hangings. They had to burn in an upright position. They required a supply of fresh air for combustion. They had to remain within reach to be lighted and and extinguished. Many were so dim they could tolerate no shades. All were relatively expensive for the amount of light they gave.

Modern light sources have none of these limitations. They can be placed anywhere, in any position. They can be totally enclosed, hidden out of sight and reach, and remotely controlled. Their brightness is usually so great they demand shading or diffusion. They are so cheap and efficient it is economically feasible to produce any desired effect and almost any amount of illumination. They can be controlled to a degree never possible with flames.

But the tradition of the flame has long retarded lighting progress. Until very recently designers have adhered to the candlestick and the oil lamp in the creation of electric light fixtures. They have placed them on tables, stuck them out from walls and hung them from ceilings without thought of the essential differences between flames and incandescent lamps.

Yet these same designers long ago accepted central heating and air conditioning in place of the log-fire of the Tudors. They freely use elevators despite the beauty and grace of the circular staircase so perfectly developed at Blois. They have used steel rather than adhere to the limitations of wood and masonry. Why should they not use the advances made by modern lighting as logically and as freely?

Only within the last few years have the fetters of the past been sundered from their hold on lighting. Architects and designers have discovered new ways to use modern light sources. They are beginning to light the things to be seen instead of letting the light source command first attention. They are literally "designing in light"; making light compose and organize their interior compositions rather than unbalance them as often has occurred in the past.

The tradition of the flame will doubtless always remain, just as the fireplace, the stairway and good old-fashioned masonry will never be lost. But traditional lighting fixtures will be used decoratively to complement controlled and efficient lighting, as the fireplace, whether used or not, survives with central heating.

Modern Interior Lighting

PART ONE

AMERICAN ARCHITECT REFERENCE DATA

No. 14, November, 1934

A DECADE ago practically all interior lighting by electricity used *fixtures* of either direct, semi-indirect or totally indirect type. Today these three kinds of light sources have been supplemented by panel and cove lighting, column, pilaster and beam lights, luminous light boxes, niches and coffers, spotlights and "down" lights. The ordinary incandescent lamp has found new forms and greater adaptability, and three types of gas-filled tubular light sources have entered the field bringing color as an added tool for those who would "design in light."

These advances have accompanied a wholly new trend in lighting with new and better concepts and standards of interior artificial illumination. They enable the architect to provide light according to mood as well as need. They free him utterly from the past domination of the light fixture as a major element in his interior designs: now he can subordinate the light source to the things to be seen.

It is the architect's opportunity—and in truth, his obligation—to design building interiors for nighttime effect as well as day. The amateur selection of light sources, brought about by leaving their choice largely to the client as a last minute decision, has ruined too many good projects to permit its continuance. Light and shade have always been an essential part of an architectural composition; why should the daytime aspect be spoiled at night by inept, if not actually bad, artificial lighting?

Moreover, the architect's relation to lighting is further established when it is fully appreciated that both initial cost and operating cost of proper lighting are directly related to the color, texture and surface finish employed on walls, ceilings, floors and even the furnishings of any room. If *efficiency* is the primary objective in lighting design the choice of surface treatments is relatively limited. If *appearance,* including styling or decorative treatment, is the first consideration, the choice of light sources and their disposition is largely governed by the selected colors, textures and contrasts to be illuminated.

MODERN LIGHTING STANDARDS

GOOD lighting, in conformity with the modern concept, should comply with these six standards:

(1)—General lighting should effectively illuminate all objects and areas to be seen with due regard to their relative importance in the interior composition. This implies a general level of illumination adequate for eye comfort throughout the room; elimination of dark shadows and sharp contrasts while preserving soft shadows for roundness and relief, and lighting emphasis on those parts which should command first attention.

(2)—Light sources should be subordinated in visual importance to the things they are intended to illuminate, except in rare instances where the light source itself is wanted as the dominant decorative element. Unless so effectively concealed or counterlighted that they are not apparent, light sources have extremely high attention value and readily dominate the scheme when in use. If visible they should usually be so disposed as to attract the eye to the major features of the room rather than divert attention to themselves.

(3)—Glare must be completely eliminated. Glare is the result of intense brightness in concentrated areas within the direct line of vision. It may be produced by excessive brightness of visible lights, by reflections of bright lights from polished or only slightly diffusing surfaces, and occasionally by extreme contrasts of light and shade. To assure its complete elimination it is usually necessary to employ means of diffusing light at its source or to use finishing materials throughout the room that diffuse or absorb rather than reflect light sharply.

(4)—The level of illumination should be adequate for the type of eye-work required in the room. Local lighting may supplement general lighting to provide



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Left: "Eye operation" at the Ophthalmology Institute, Columbia Presbyterian Medical Center; James Gamble Rogers, Architect. (Photo copyrighted by F. S. Lincoln). Lighting from recessed light boxes with sloping prismatic control lenses. Above: Ceiling illuminated by vertical panels in reception room in offices of Johns-Manville. Shreve, Lamb & Harmon, Architects

adequate illumination of work at machines, desks, reading tables and other fixed points, but this high level local lighting should always be accompanied by enough general illumination to minimize contrasts and eye strain.

It may be noted here that there can be no such condition as over-illumination from artificial sources provided there is no glare. Outdoor daylight levels run up to 10,000 units; indoor natural lighting to several hundred. Rarely does artificial lighting today exceed 20 units, though the tendency is upward and for some purposes may reach 100 or more units.

(5)—General illumination should be related to or controlled to suit the occupant's mood. There are important psychological reactions to light. Worship, introspection, contemplation and physical relaxation are aided by relatively low lighting levels. Gaiety, keen thinking and great mental and physical activity are favored by high levels. In theatres, houses, and some types of restaurants it is particularly important to control lighting according to mood; in stores and shops and in some institutional buildings it is necessary to employ the amount of light that will produce the most favorable psychological reaction; in offices, factories, schools and shops where work is done, it is essential to select illumination levels that will eliminate eye-strain.

(6)—Appearance of light sources should be carefully related to the style, decorative treatment and general composition of the room. In style, shape and finish visible fixtures or luminaires, or the means employed to conceal hidden sources, should harmonize, both lighted and unlighted, with the architectural character of the room.



DEFINITIONS OF TERMS RELATING TO ILLUMINATION

Absorption—The loss which results when light strikes any object or traverses any medium. The amount of light absorbed expressed as a percentage of the total amount striking the object or medium, is known as the absorption factor.

Brightness—A quantitive term used to define the luminous intensity of a surface in relation to its projected area as viewed from a given point. It refers to a light source rather than to a lighted object. It is independent of distance. It is measured in lamberts, foot lamberts, candlepower per square inch, lux and other terms of importance to the technician.

Brightness Ratio—The ratio of one bright surface to another. In general, it can be said that the brightness ratio of any two surfaces within the same field should not exceed 100 to 1 for comfortable vision.

Candle—The word refers to the International Candle, which is the unit of luminous intensity. Candlepower is luminous intensity expressed in candles.

Coefficient of Reflection—The ratio of the total light reflected by a surface to the total light falling upon it, expressed as a percentage. (See Absorption)

Coefficient of Transmission—The ratio of the light transmitted by translucent and transparent objects to the total light falling upon them, expressed as a percentage.

Coefficient of Utilization—The ratio of the useful light (upon the working plane) in a room to the total light emitted by the lamps in that room, expressed as a percentage.

Louver or Spill Shield—A shield placed in the path of light to eliminate a part which is not desired.

Lumen—The unit of luminous flux: the amount of light (1) emitted over a given solid angle around a source or (2) received on a given area. It differs from the candle or foot-candle in that it takes account of the extent of space or area over which the light is distributed. For a given illumination the flux or amount of light (lumens) varies directly with the area over which this illumination is distributed. With reference to light received on a given surface, one lumen equals one foot-candle distributed over one square foot. Lumens = Average foot-candles x sq. feet of area. Conversely, Foot-candle = lumens per square foot.

Luminaire—A lighting fixture or complete unit; officially adopted by the Illuminating Engineering Society to denote the combination of light source with its direct appurtenances, such as globe, reflector, refractor, housing and support.

Reflection—The light flux striking an object which is turned back (i. e., is neither transmitted nor absorbed). The percentage of incident light reflected by an object is called its reflection factor and is used as a criterion of the reflectivity of that particular object. The degree to which an object receiving light upon its surface can reflect it is called its **reflectivity.**

Reflector—Any object which to a marked degree possesses the property of reflecting light; specifically a device for redirecting light by reflection.

Refractor—A device (generally of glass) designed to control the direction of light emergent rays.

Room Index—A constant used in lighting calculations which takes into account the proportions of the room in conjunction with the height of lamps.

Transmission—The passage of light through an object or medium. The ratio of transmitted light to incident light is known as Transmission Factor of an object, or of a material of specified thickness.

Working Plane—In the design of lighting installations for use in factories, mills, and other work places, a plane in which the work is presumed to be done. It is ordinarily assumed to be about 30 inches above the floor.

Diffusion—The scattering of light rays so that they travel in different cross directions rather than in parallel or radiating lines. Too much diffusion makes rounded surfaces and relief appear flat. Such an effect is referred to as "Flat Lighting."

Distribution of Light—The manner in which a light source or lighting unit emits its flux in various directions. The characteristics of light distribution, are commonly recorded in the Candlepower Distribution Curve.

Effective Lumens—The light, measured in lumens, which is useful in providing the desired illumination. It is commonly taken as being the product of the area illuminated and the level of illumination. Thus, an area of 1,000 square feet illuminated to 5 foot-candles would require 5,000 effective lumens.

Flux—A term commonly used to describe the quantity of light given out by an illuminant measured in terms of visual sensation. Its unit of measure is the Lumen (q.v.)

Foot-candle—The unit of illumination defined as the illumination at a point one foot from a source emitting one candlepower in the direction of the surface. It is the illumination received when one lumen of light falls on one square foot of area.

Lens Plate, also known as Controlens—A prismatic refracting plate placed in front of a lamp to gather and bend the light rays in desired directions

Apartment of Katherine Brush, designed by Joseph Urban Associates. Recessed bookcase niches lighted by soffit panels. Ceiling fixtures consist of a series of metal light troughs diffusing light across ceiling and throughout room by diffuse and specular reflection. Photo: F. S. Lincoln

LIGHT SOURCES AND LIGHTING MATERIALS

THE tools which the designer uses to produce lighting effects include incandescent lamps and gaseous tube sources, reflectors, diffusing and transmitting glasses, lenses, prisms, and the surfaces of the room itself. Basic data concerning these sources and materials follow:

Incandescent Lamps are made in the standard wattages, types and dimensions shown in Table 1 and in other special styles not shown. Bulbs may be "clear," "inside frosted," "clear colored" and "diffuse colored." Inside frosted finish is standard in the range of 15 to 100 watts, and readily obtainable in larger sizes, combining the advantages of some diffusion with minimum absorption of light. Clear bulbs never should be used exposed; in fact, even frosted lamps are too bright for comfort and it may well be said that in general all lamps should always be shaded or shielded from direct vision.

Wherever possible architects should design light sources which will permit the use of standard line incandescent lamps designated as shapes A and PS in Table 1. These are universally available and are sold in such quantities that their prices are lower than any other types. The other bulb shapes listed are in standard production but are not always carried in stock by local dealers and are more costly.

Some new special types of importance in lighting of building interiors are: (1) Three-intensity lamps having two filaments of different wattages which may be lighted singly or together by means of three circuits and a special three-contact receptacle. For example, a bulb having a 200-watt and a 300-watt filament may operate at 200, 300 or 500 watts. These lamps are useful in giving a considerable range of lighting intensities with the minimum number of fixtures or outlets. (2) Lumiline lamps, which are tubular lamps requiring support at each end in special sockets. By their use practically continuous lines of light may be installed in narrow spaces. They are made in several colors including white, straw, orange, emerald green, moonlight blue, rose and surprise pink, which may be used exposed.

Gaseous Tube Light Sources are essentially arc lamps. They require some auxiliary device, such as a transformer or reactor, for their operation. Various types of gases used within these tubes produce light of different colors. There are three basic types: High voltage discharge lamps (commonly but often erroneously known as neon tubes), hot cathode gaseous conductor lamps and mercury vapor lamps.

High voltage discharge lamps employ glass tubes one-third to one-half inch in diameter and in any length desired up to voltage limits permitted by local rulings. The maximum length is generally 50 ft. which requires 15,000 volts for its operation. The transformers serving such tubes range in size from 8"x5"x6" to 14"x10"x6" according to the length and voltage of the tube served. These transformers should be as near as possible to the tube terminals to minimize the necessity of excessive high voltage wiring which requires specially insulated conductors. Where radio interference is a consideration—a con-

TABLE 1. DIMENSIONS OF MAZDA LAMPS FOR SERVICE ON STANDARD LIGHTING VOLTAGES—(110-115-120)

Watts	Diameter	Over-All Length	Base
Standard Line "A" Bulbs			
15	2 1/8	3 5/8	Med.
25	2 3/8	3 15/16	"
40	2 3/8	4 1/4	"
50	2 5/8	4 15/16	"
60	2 5/8	4 15/16	"
75	2 5/8	5 5/16	"
100	2 7/8	6 1/16	"
Standard Line "PS" (Pear Shaped) Bulbs			
150	3 1/8	6 15/16	Med.
200	3 3/4	8 1/8	"
300	4 3/8	9 7/16	Mogul
500	5	9 13/16	"
750	6 1/2	13 1/8	"
1000	6 1/2	13 1/8	"
1500	6 1/2	13 1/8	"
Tubular "T" Bulbs			
25	0 13/16	5 1/2	Inter.
25	1 1/4	5 3/8	Med.
40	1	11 7/8	"
75	1 1/4	11 7/8	"
100	1 1/2	34	"
150	1 1/4	11 7/8	"
Double Ended "Lumiline" Bulbs			
40	1	12	Special
30	1	18	"
60	1	18	"
Low Wattage "S" Bulbs			
3	0 3/4	1 7/8	Cand'le
6	0 3/4	1 7/8	"
6	1 3/8	2 5/16	Inter.
6	1 3/4	3 1/2	Med.
10	1 3/8	2 5/16	Inter.
10	1 3/4	3 1/2	Med.
Round "G" Bulbs			
25	2 5/16	3 9/16	Med.
25	3 1/8	4 7/16	"
40	3 1/8	4 7/16	"

SHAPES OF BULBS



BASES: Cand'le candelabra Inter. intermediate Med. medium Mogul mogul

Incandescent lamp bulbs are designated by number and letter, the number indicates the diameter in eighths of an inch; the letter indicates the shape as above. Thus, A-19 designates a standard line lamp having a diameter of nineteen eighths of an inch, or 2 3/8 inches.

dition that occurs in the majority of installations—a suitable condenser must be shunted across the transformer terminals.

The light emitted by these high voltage discharge lamps is not of high intensity, permitting the tubes to be used exposed without serious eye strain. The color of light produced depends upon the gas used, such as neon, argon, mercury, helium, etc. Their decorative possibilities for interior lighting are extensive, though they are most familiar because of their common use in illuminated signs.

Hot cathode gaseous conductor lamps represent a new type for use on standard voltages. They produce a considerable volume of light and must therefore be concealed or shielded from direct vision. They may be disposed in much the same manner as tubular or lumiline incandescent lamps. As sources of brilliant colors of high intensity, hot cathode tubes are far more efficient than either incandescent lamps with colored bulbs or colored shields, or the high voltage discharge tubes.

These hot cathode gaseous conductor lamps have a tubing one inch in diameter and a length of 27 to 50 in. per unit. The tube requires a space 4 in. over-all to accommodate the terminals which are larger than the tube itself. One transformer with control apparatus, measuring either 6″x8″x22″ or 10″x10″x10″, is required for each lamp. Standard insulated wire may be used from the control to the lamp and the control can be placed in the fixture itself close to the tube or remote from the lamp providing the run of wire does not exceed 20 ft. measured on one side of the circuit.

Mercury Vapor Lamps of both high and low pressure types produce light rich at the blue-green end of the spectrum whereas incandescent lamps produce light inherently rich at the red and yellow end. By combining incandescent lamps with mercury lamps (preferably in concealed light sources) light of very satisfactory white appearance is secured at high efficiency.

Reflectors are used to control the distribution of light from lamp or tube sources by shielding the light source from certain directions and by reflecting the light thus shielded in desired directions. Reflector surfaces may be polished and reflect like mirrors, in which case the shape of the reflector accurately controls its distribution characteristics, or the reflector surface may be of diffusing type, in which event the reflector shape only partially controls distribution.

Materials commonly used for polished or specular reflectors are silver on glass, chromium, aluminum, rhodium and prismatic glass; for diffusing reflectors, oxidized or etched aluminum, white paint, vitreous porcelain enamel, aluminum paint, and dense white glasses. White plaster is an excellent diffusing reflector but is too difficult to keep free of dust for practical use as a direct reflecting surface behind lamps. The reflection factors of typical materials are shown in Table 2. The characteristics of reflectors of various basic types are shown in Fig. 1.

Lenses and Prisms are important tools in controlling the distribution of light. Lenses are employed with reflectors to form light beams of accurately regulated dimensions. They are used principally on spotlights, down-lights and other concealed sources where the light opening must be very small but the amount of illumination considerable. Prisms, such as the Fresnel glass used in lighthouses, and various other types of prismatic glasses are also used with reflectors to bend light beams. See Fig. 1.

Diffusing Materials, other than those used as reflectors, will be found in Part II. Of all the materials used to transmit light in its architectural applications, glass is by far the most important. The forms commonly used are:

TABLE 2. REFLECTION FACTORS FOR TYPICAL MATERIALS AFFECTING LIGHTING
(Based on color characteristics of incandescent lamps)

Material	Reflection (per cent)
INTERIOR MASONRY MATERIALS	
Plaster — white	90–95
Terra Cotta	
White and cream—smooth and matte	60–80
Caen Stone	55–65
Limestone	35–58
Marble	
One side polished	30–71
Impregnated	27–54
Alabaster	
Veined	49–67
Colored	27–29
Grey Cement — natural	20–30
Granite	20–25
Red Brick — natural	10–15
INTERIOR WOOD FINISHES	
Light Oak	25–35
Dark Oak	10–15
Mahogany	6–12
Walnut	5–10
METALLIC REFLECTORS	
Vitreous Porcelain Enamel on Steel	
Matte White	60–83
Glazed White	65–77
Matte-Finished Metal	
Oxidized or etched aluminum	70–89
Aluminum Paint	60–65
Polished Metal	
Silver	90–92
Chromium	63–66
Aluminum	62
Monel metal	49–55
Chromium-nickel (stainless) steel	55
PAINTED SURFACES	
Flat White	75–85
Gloss White	75–80
Cream	65–75
Bright yellow	60–70
Buff	52–56
Light grey	35–50
Dark Grey	20–25
Very light blue	45–55
Spanish or bright blue	5–10
Apple or pale green	40–55
Willow or medium green	15–25
Olive green	12–15
Spanish or bright orange	35–40
Cardinal or dark red	20–25
Medium brown	25–35
Dark brown	8–10



Prismatic lenses in ceiling light boxes used for side-wall lighting in apartment of H. H. Porter; Rosario Candela, Architect. Note that unit placed over door for symmetrical spacing projects light to the right as well as toward wall

Solid Opal Glass—A homogeneous white glass, usually providing a high degree of diffusion.

Flashed or Cased Opal Glass—Crystal glass with a thin coating of highly diffusing opal. The clear glass may be in color. An amber tinted glass gives a warm, soft light; a blue glass, a cold white light; and a pink glass produces a tint flattering to the complexion.

Opalescent Glass—A partially devitrified glass with crystalline material more or less uniformly scattered throughout. Tinges of color are usually visible and variegated effects are often present.

Alabaster Glass—Semi-diffusing glass usually of a gray waxy appearance, with diffusing material held in colloidal suspension.

Configurated or Obscure Glass—Crystal glass with its surface embossed in patterns or roughened, for decoration and scattering of light.

Depolished Glass—Either sandblasted, acid-etched, or ground; sometimes in patterns.

Rods—Solid, clear or depolished, refracting light predominantly transversely somewhat as ribbed or fluted glass.

Tubes—Clear, or depolished inside or outside, thus providing several steps from flashing high lights to silvery sheen.

Colored Glass—Having coloring matter within the glass.

Ceramic Coated Glass—Glass with a fired coating of white or colored, more or less diffusing, material.

Cathedral Glass—A very wide classification covering glasses sometimes obscured in no definite pattern, frequently tinted, variegated, or opalescent. A large group derives its texture from the presence of bubbles, "seeds," "strings," crackles, etc.

Moulded Glass—Sculptured grilles, plaques, etc. in pressed glass, often with diffusing finishes and colors. Highly valuable for luminous detail. This class also embraces several types of structural glass.

Carved Glass—Any type of glass sandblasted in patterns of variable depth. May be tinted or opaqued.

Structural Glass—Pressed-glass building blocks, tile, etc., used in place of opaque materials. Blocks are made solid, hollow, and evacuated, embossed for decoration and scattering of light. Available in crystal or diffusing glass.

The most important of these glasses for light boxes, panels, diffusing windows and the like are flashed opal glasses; for the thin coating of opal on crystal glass produces excellent diffusion and uniform appearance with a much higher transmission of light than is possible with solid opals or frosted crystal glasses.

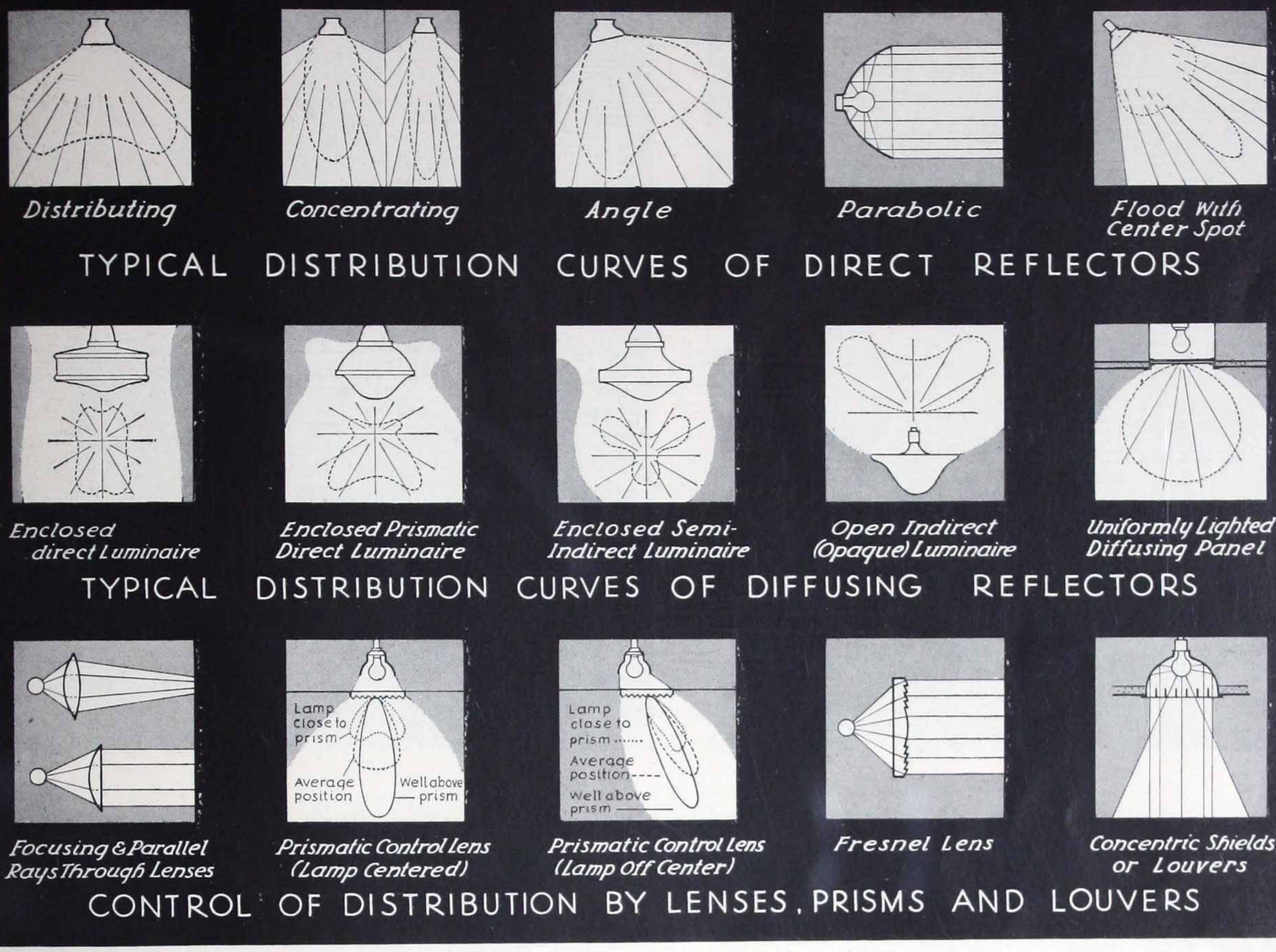


Fig. 1—Methods of controlling the distribution of light by reflection, refraction and diffusion

The transmission of many ground and roughened glasses is increased when the rough side of the glass is toward the light source. This is fortunate, because maintenance reasons generally require the rough surface to be turned in.

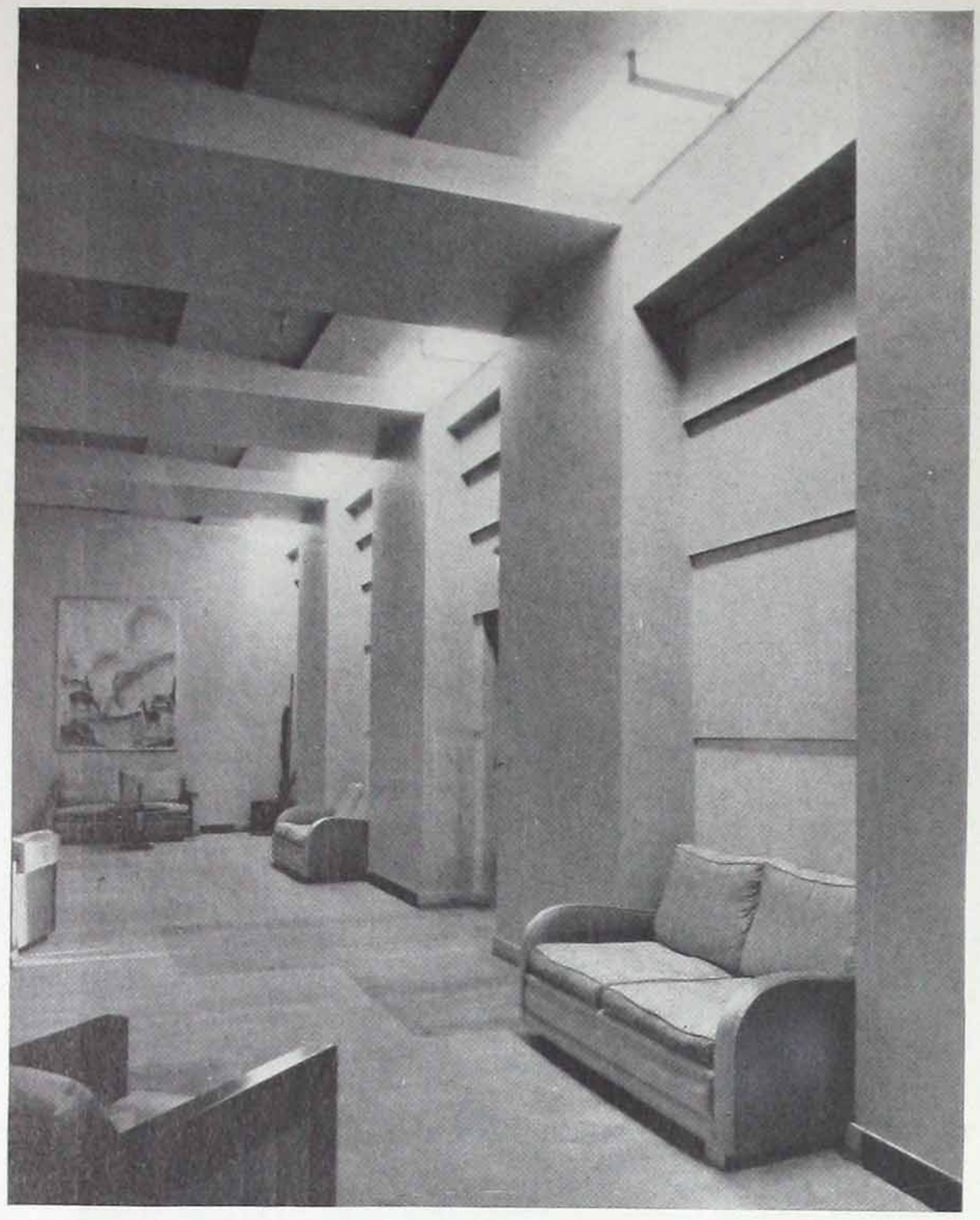
The amount of light reflected by glass affects its daytime appearance. The higher the reflection factor the whiter the surface will appear in daylight. For example, if a definitely white surface is desired, solid opal glass should be used. In order from white to gray, the other materials are flashed opal, opalescent, obscure and ground glasses.

Surface Materials used on walls, ceilings, furnishings and even floors, markedly affect the selection and use of light sources. If the light source itself is diffused through such materials as flashed opal glass, it is possible to tolerate polished room surfaces without creating a troublesome glare, but if the light source is unshielded or very bright, it will glare from polished or reflecting surfaces; hence unshielded sources should only be used where they will project toward diffusing surfaces. Failure to appreciate this relation between the brilliance or glare-producing qualities of the light source and the characteristics of room surfaces is a common cause of unpleasant glare and bad lighting.

Another aspect of surface materials is that their absorption of light (which varies with the material, its texture and its color) affects the quantity of light which will be delivered by redirection. See Table 2.

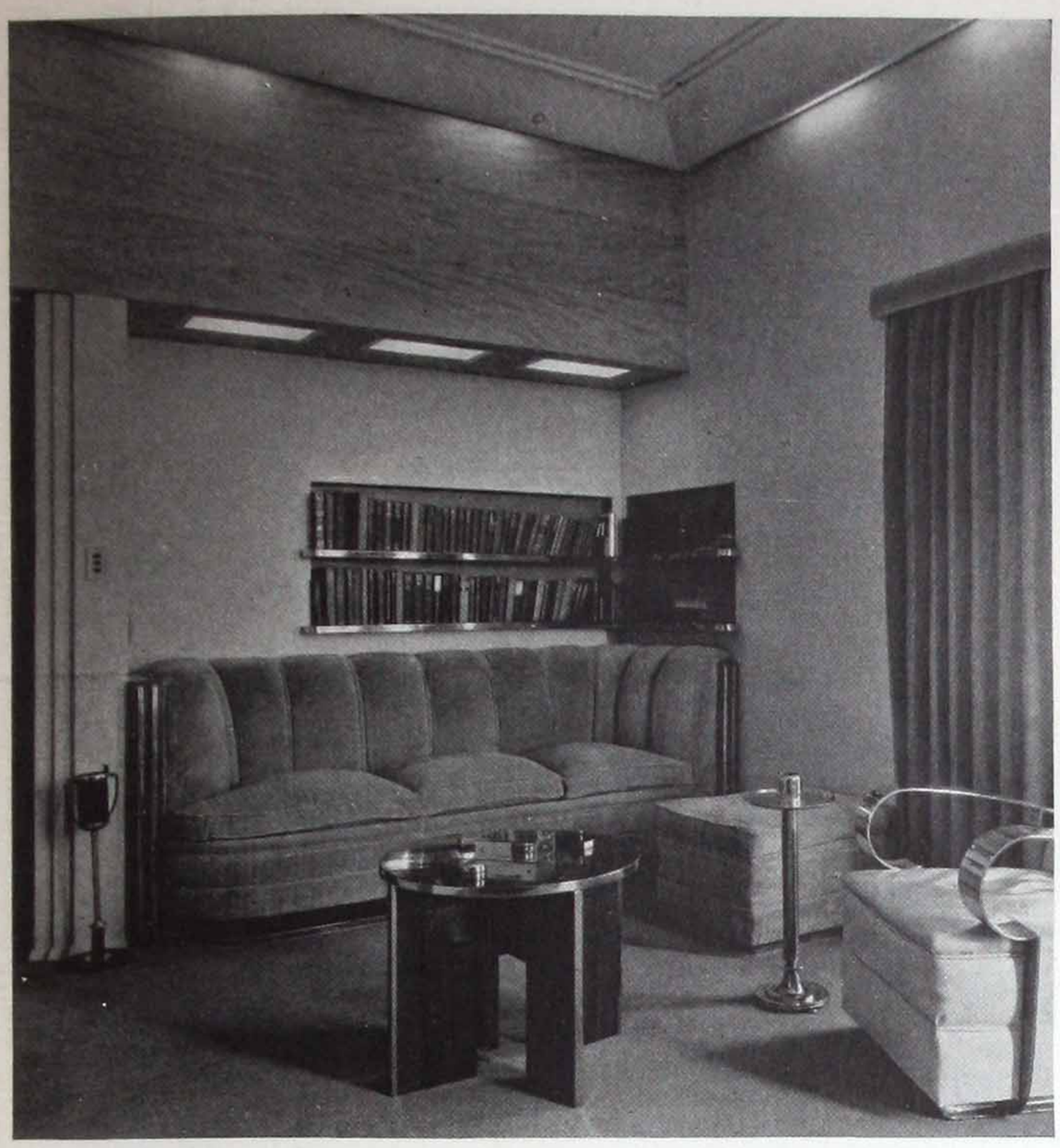
From this table and from calculation data to follow in Part II it will become evident that if efficient lighting is wanted at minimum cost, the ceilings should be white, the walls and all other available reflecting and diffusing surfaces, light tints of buff, cream, yellow or green. This is common practice in industrial plants, offices, stores, etc. But the cost of electric lighting is so low, that efficiency may be subordinated to appearance in the great majority of installations.

It should also be noted that the type of light source governs the importance of surface absorption of light. The finish of walls and ceilings is least important when opaque direct lighting reflectors (industrial types) or down-lights are used; more pronounced with translucent glass luminaires and panels, and a major consideration with semi-indirect and indirect luminaires, cove lighting and other sources reflecting most of their flux from such surfaces.






INFORMATION







OPPOSITE PAGE. Upper left: Luminous box cornice in Bullock's Wilshire store, Los Angeles, for general illumination and to accentuate relief of side walls. **Upper right:** Beauty shop in same store showing lighting by vertical as well as horizontal surfaces. John Parkinson & Donald Parkinson, Architects. Photos, Associated Photographers, Inc. **Below:** Lounge, Ford Building, Century of Progress; Albert Kahn, Architect. Flush ceiling panels and illuminated side-wall panel simulating window. Photo, Hedrich-Blessing Studio. **THIS PAGE. Upper left:** Hollywood apartment with soffit lights over lounge and lights incorporated in ceiling cornice of unusual form to illuminate side walls. Herbert Ketelle & Joseph Babolnay, designers. Photo, Associated Photographers, Inc. **Upper right:** Reception office L. C. Chase & Company. Fixtures used for architectural emphasis especially designed by Eleanor Le Maire. Photo, F. S. Lincoln. **Below:** Detail of Sardi's Restaurant; Rudolph Schindler, Architect. Low placed cove lighting troughs project against a curved side wall designed for light reflection. Caricatures are illuminated from behind. Photo, Associated Photographers, Inc.

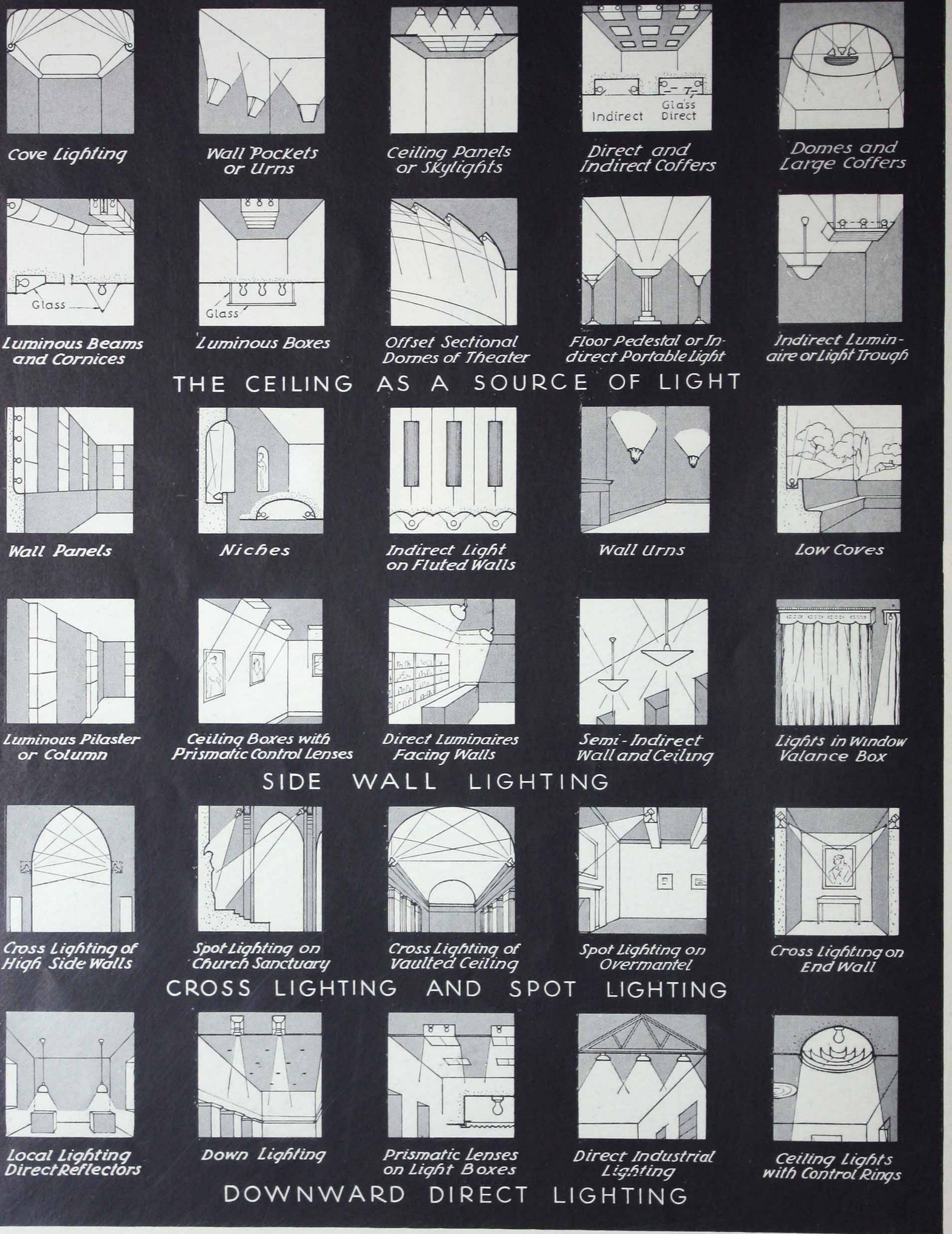


Fig. 2—Ways of using light

WAYS OF USING LIGHT

VARIOUS ways of using light for seeing (as distinguished from purely decorative applications) are diagrammatically presented in Fig. 2 as well as in many of the accompanying illustrations. The characteristics and limitations of the principal methods may be summarized as follows:

Ceiling Reflection, in which light sources are directed upon a white or light colored ceiling and thence redirected and diffused throughout the room, produces a soft general lighting of excellent quality. It is generally most effective when side walls are also of rather light tone; otherwise the ceiling may appear excessively bright and thus distract the eye by its contrast with dark walls. It is also very useful as a source of moderate-level general lighting, in the order of 3 to 6 foot-candles, when supplemented by local lighting of special areas or work surfaces at higher intensities. Ceilings may thus be lighted by coves, indirect luminaires of trough or bowl shape suspended from the ceiling, pylons or floor stands with concealed reflectors above the eye level, and wall pockets, brackets or strips like short sections of coves mounted on side walls or columns. With indirect lighting the luminaires themselves may be opaque or slightly luminous by transmitted light. See Fig. 2, for representative methods of using the ceiling as a light source.

Direct Ceiling Sources, including ceiling beams, illuminated coffers and domes, luminous false beams and cornice mouldings, and luminous glass boxes, differ from indirect ceiling reflection in that they introduce areas of relatively great brightness in contrast with the remainder of the ceiling and hence have considerable attention value. They usually have somewhat the same effect of attracting the eye upwards as an indirectly lighted ceiling that contrasts sharply with dark walls. Where this degree of prominence of the light source is desired or acceptable and where the units are arranged in a pleasing and logical pattern that gives good coverage of the room, they may provide general lighting of moderate to fairly high levels. The disposition of visible light sources on the ceiling or suspended therefrom is usually superior to side-wall lighting for the reason that it is less distressing to have them well above the eye level than in direct line of vision.

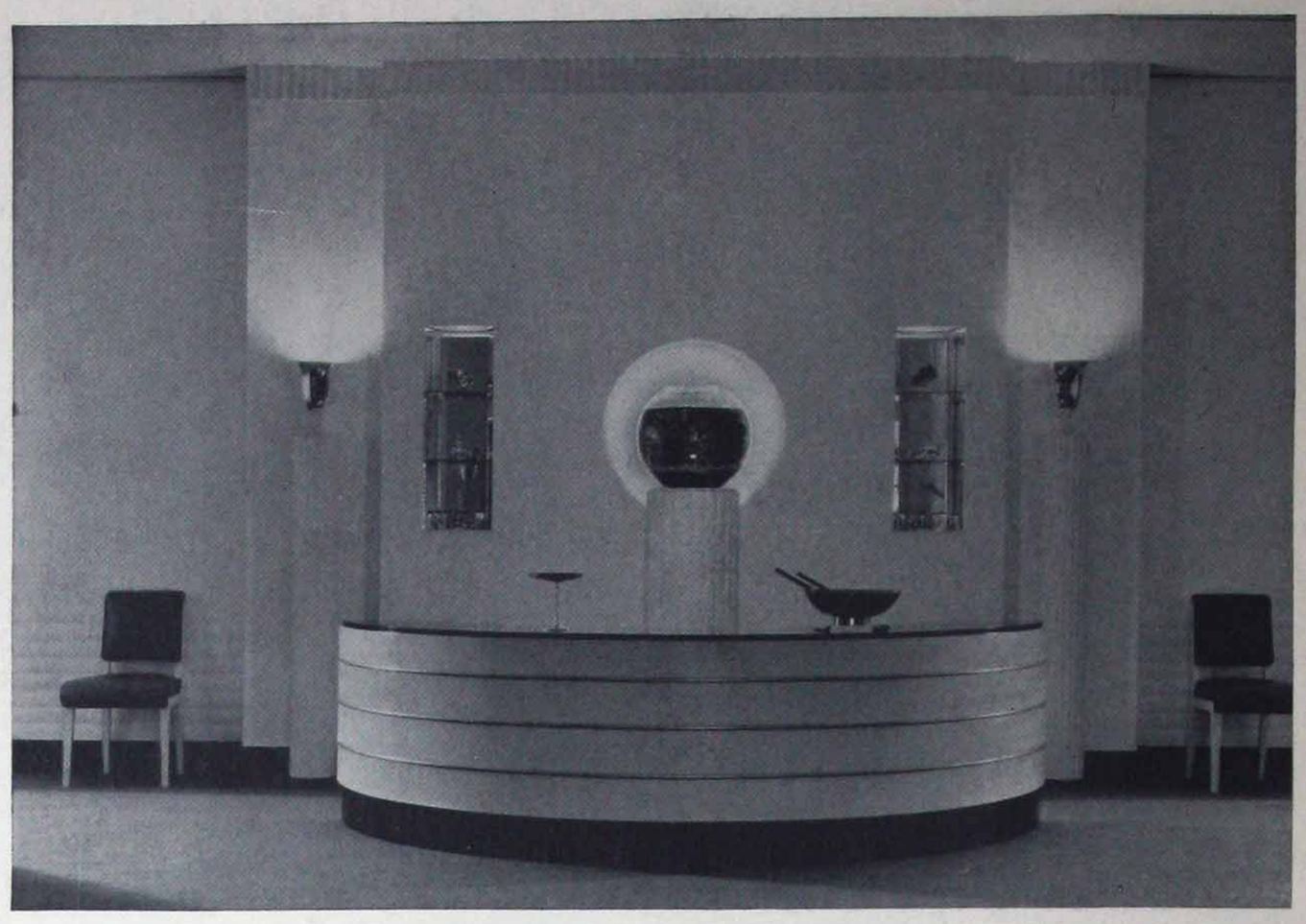
One form of direct ceiling lighting places the lamps themselves in boxes or reflectors above the ceiling level and sends controlled beams down through relatively small openings which do not greatly distract the eye. One form, called a "down light," employs an elliptical reflector equipped with lenses concealed above the ceiling level with only small apertures 4 in. or less in diameter appearing on the ceiling surface. Another type employs an open reflector having louvers or shields that cut off direct view of the lamp from all normal angles of vision, and a third uses reflectors and prismatic refracting plates or "control lenses." The light is projected downward in all cases. As a class these sources are particularly useful where the ceiling itself is unimportant to the lighting composition and where the floor level must be well lighted. Such schemes give better light control than any other commonly used method.

Indirect Side-wall Lighting, if developed uniformly over large areas and at moderate brightness levels, has substantially the same value as indirect ceiling illumination but with the important exception that it tends to form silhouettes of persons or objects viewed toward the wall. Indirect side-wall light sources are shown in Fig. 2. They include: low coves concealed behind built-in furniture; coves incorporated in window head valance boxes or above bookcases, show cases and similar built-in units; indirect lighting produced by projecting opaque light troughs that reflect against the adjacent side wall; and soffit lights in ceilings or beams which, by means of prismatic reflectors, direct most of their light flux on the adjacent side wall.

Direct Side-wall Lighting, using such sources as luminous wall panels, niches, wall urns and side-wall brackets of any type have high attention value because they are in direct line of vision. Recessed sources tend to produce sharp contrast between the lighted sections and the indirectly illuminated areas which surround them. Side-wall lighting is valuable for decorative and architectural purposes and for good illumination of vertical surfaces, such as manikins and dress models in shops and stores, but they do not provide uniform distribution of their light flux on the horizontal plane of the room.

Cross Lighting may be used on walls or on vaulted ceilings as illustrated in Fig. 2. As the name implies, projectors (usually concealed or recessed and shielded from the eye level) cast their light across the room from both sides or from two different angles toward the same area. This method is particularly useful when side walls well above the eye level carry murals, mosaics or other important decorations requiring good illumination from invisible sources. It also serves as a means of correcting spottiness caused by cove lights, wall brackets, etc., by cross lighting the shadowed areas.

Spotlighting is one-way lighting, usually employing projectors with lenses but sometimes with reflectors only, used to give special illumination of a limited area as in theatre practice. A mural, statue, oil painting or other axial feature may thus be made to dominate the lighting composition. The spotlights must be so located as to be out of direct line of vision and to produce no troublesome reflections or glare. Possible locations may usually be found within



Lounge, Ford Building, Century of Progress. W. D. Teague, Designer. Light is here used as a definite part of the architectural composition. Two side-wall urns on the pilasters provide general illumination by reflection from side wall and ceiling. Niches behind counter are lighted by soffit lights. Decorative bowl is centered in a semi-spherical wall niche indirectly lighted around its perimeter. Photo, Hedrich-Blessing Studio

chandeliers of special design, in ceiling beams or coffers or in columns or wall brackets. See Fig. 2.

Ceiling and Side-wall Fixtures and Luminaires are by no means made obsolete by modern lighting standards, though their selection and use is now a matter of intelligent consideration rather than mere habit or precedent. The greatest value of luminaires are their flexibility and economy in securing uniform distribution of light over large areas with the minimum of outlets and lamps.

The modern fixture, however, is not merely an adaptation of an old candle, oil or gas device with incandescent lamps at the ends of metal arms, but rather incorporates in its construction reflectors, refractors and other devices for controlling the distribution of light and limiting visible brightness. It may follow traditional lines and may even have electric candles exposed, but the ingenious designer conceals in the body or structure the light sources which really furnish the illumination.

The use of fixtures and standardized luminaires is too familiar to warrant detailed discussion here. Complete design data can be obtained from manuals and catalogs issued by leading manufacturers of such equipment and of Mazda lamps. Factors governing the selection and proper use of direct, semi-indirect or totally indirect luminaires will be found in Part II of this article. Considerations governing the design or selection of lighting fixtures of period character are clearly indicated in the general presentation of modern standards.

Portable Fixtures, including table and floor lamps, belong strictly in the local lighting classification and are invaluable for stepping up lighting intensities at work centers such as desks, tables and at reading chairs. Suspended direct lighting opaque reflectors hung low enough so that the reflectors cut off all view of the lamp, have the same function in commercial and industrial applications over machines and work surfaces.

Reliance upon portable lamps for general illumination is rarely good practice though currently popular in residence work. Such use of relatively high intensity areas scattered throughout the room completely distorts the daytime composition, often attracting attention to areas of minor importance and neglecting others that should normally dominate. They leave dark shadows beneath furnishings and cause excessive eye-strain due to the sharp contrasts of light and deep shade.

DECORATIVE LIGHTING

THE foregoing general survey of lighting sources and methods relates only to their functional uses; their decorative or appearance aspects are considered to be a matter easily controlled by the architect. But in addition to functional lighting, modern light sources can be used also for pure decoration in light and shadow, form, line and color. Such ornamental applications are of infinite variety, ranging from simple shadow boxes from which light shines through stencils and colored apertures to cast light patterns upon walls and ceilings to intricately developed coloramas, but these are beyond the scope of this article. Complete data can readily be obtained through manufacturers of lighting equipment and from public utility service departments.



F. S. LINCOLN

Modern Interior Lighting

PART TWO

AMERICAN ARCHITECT REFERENCE DATA

No. 15, December 1934



PEYSER & PATZIG

An indirectly lighted artificial window and indirect vertical corner coves illuminate the oval private office of Nathan Ohrbach, New York. The room occupies interior space and is completely air conditioned. Designed by Kenneth C. Welch, architect.

F. S. LINCOLN



Right: A modern chandelier of glass and metal retaining the traditional branching form and decorative character, in which most of the body of the lamps is shielded from direct vision and light is cast largely toward the ceiling and side walls. Apertures in the metal cups and hub allow a small amount of light to "spill" through the glass bracket arms, enhancing their decorative value without glare Title page: Chandelier and wall brackets need not use the candle type of light to harmonize effectively with rooms of well defined traditional or period character.

Modern Interior Lighting

PART TWO

AMERICAN ARCHITECT REFERENCE DATA

No. 15, December, 1934

MANY ELEMENTS employed in modern lighting involve no special dimensional or planning considerations other than proper spacing and capacity of outlets that serve them. In this category fall luminaires, drop lights, portable floor and table lamps, and decorative ceiling fixtures and wall brackets. In this group also belong many new "fixtures," developed within the last year or two by progressive manufacturers, in which the traditional character and eye appeal of the ornamental chandelier and wall bracket have been blended successfully with reflectors and refractors that conform to modern concepts of good lighting.

Such units deserve special consideration in any study of interior illumination because they satisfy the normal desire to see the source of light; they retain the values inherent in the tradition of the flame as a light source; they have unlimited decorative possibilities; and they can provide almost any desired illumination level without glare and under complete control. They represent also, a logical and economical way of modernizing the lighting of interiors by merely taking the place of inadequate and glare-producing fixtures without expensive reconstruction for new outlets or built-in sources.

Light sources that are built into the structure affect preliminary planning and usually require special detailing on architect's drawings. Performance characteristics, design limitations and space requirements of these less familiar light sources follow:

Cove lighting requires a fairly high ceiling free of beams and other obstructions. The side wall or ceiling close to the light source should be vertical or nearly so; the maximum rise should be at the center of the ceiling, but an arc of a circle is not desirable as the lamps produce a spotty effect at the cove. The narrower the room, the easier it is to secure uniform lighting.

Coves should be above eye height and must be accessible for relamping and cleaning. They should be sufficiently below the ceiling to give the light a chance to "spread" and thus avoid spottiness. See Fig. 3 for recommended design practice. Unless the cove is covered with dust-tight glass, plaster should not be used to form the reflecting trough behind the lamps as it quickly collects dirt or dust and must be frequently painted to maintain its efficiency.

Reflectors or prismatic glass covers should be used where wide distribution is necessary, as in the case of a wide room or coves close to the ceiling. Concentrating specular reflectors of high efficiency placed close enough together to prevent spottiness are recommended for best results in relatively wide rooms. Prismatic lens plates and Fresnel lens sections may be used with reflectors to form a sheet of light projecting at a narrow angle across the ceiling.

Cove dimensions depend upon the type of reflector and the wattage of lamps. A three-inch trough using tubular or lumiline lamps represents the smallest practical cove with limited light output. Allow from 5x5 inches for 40 watt lamps to 10x10 inches for 200 watt equipment. See Fig. 3 for dimensions of representative units.

Ceilings lighted by coves high up on the wall are likely to reveal any surface imperfections or irregularities, especially if painted with gloss paints. Where the coves cannot be dropped well below the ceiling line it is usually better to use a textured treatment, such as sand finish or palm finish, and to let the light bring out the texture, than to attempt to produce a mechanically true ceiling.

Efficiency of cove lighting varies widely. Under very favorable conditions a plaster cove may have a coefficient of utilization of 18% to 20%. With specular reflectors of high efficiency the coefficient would rise to 25% or more. If the reflection factor of the ceiling is less than 70% these values must be reduced proportionately. See section on Lighting Calculations for the application of these data.

Indirect ceiling illumination of any other type, such as from reflectors mounted in pylons, floor stands, side-wall brackets or suspended indirect luminaires and light troughs, should follow the principles indicated for cove lighting. The light source should be above eye level, the light should have a chance to spread before reaching the ceiling, and distribution of these sources should be such as to avoid spottiness or unequal lighting of ceiling areas. When such sources project their light vertically or nearly so, the character of the plasterwork is of little importance and even beams and other obstructions often may be tolerated.

Panel lighting for ceilings, side walls, columns, pilasters or soffits requires space behind the glass panel face to contain the lamps and some form of diffuse reflecting surface. Important requirements are: (1) A simple means of access for relamping or maintenance; and (2) the glass face should be uniformly lighted or the lighting uniformly graded as desired, without revealing the position of the lamps or showing spottiness. This requires the right combination of background reflectors, lamp spacing and choice of diffusing glass. Obviously, the mechanical construction of built-in lighting units must be of sound design, holding the glass securely but with proper provision for expansion, and having means of access to the lamps and interior surfaces.

The reflecting niche may be rectangular or curved provided a good diffusing surface is employed, such as flat white paint or matt enamel. Shapes commonly used and their performance characteristics are shown in the diagrams accompanying Table 8. Lamp spacings for visual uniformity depend on the cover glass used, as follows:

	Distance from Glass "D"	Spacing between Lamps "S"
Flashed opal glass.....	4"	6"
Flashed opal glass.....	6"	9"
Flashed opal glass.....	8"	14"
Sand blasted or acid etched crystal glass ...	12"	4"

The wattage of the lamps makes practically no difference in the uniformity of brightness. With a high reflection background or where a grille overlay is used, the spacing of lamps may be somewhat wider than above for the same distance from the glass. All measurements are to the centers of the lamp bulbs. For data on the transmission, reflection and absorption factors of various translucent materials see Table 3.

If the glass of the panel is not one piece, the dividing strips or frames should come in the darker spaces between lamps.

Sockets should be of porcelain, and wire used in light boxes should be asbestos covered or at least have slow-burning insulation to withstand the heat generated in the enclosed space. Each box should have some means of ventilation or should have ample radiation surface to dissipate this heat.

Frosted, carved, etched and ground glasses are such poor diffusion mediums that they should be backed by a plate of flashed opal glass or else the lights should be placed at one or both sides of the light box, as for an indirectly lighted niche, and the background relied upon for uniform effect.

Luminous Boxes, beam strips and coves are governed by the same considerations as the design of lighted panels. Performance characteristics are given in Table 8.

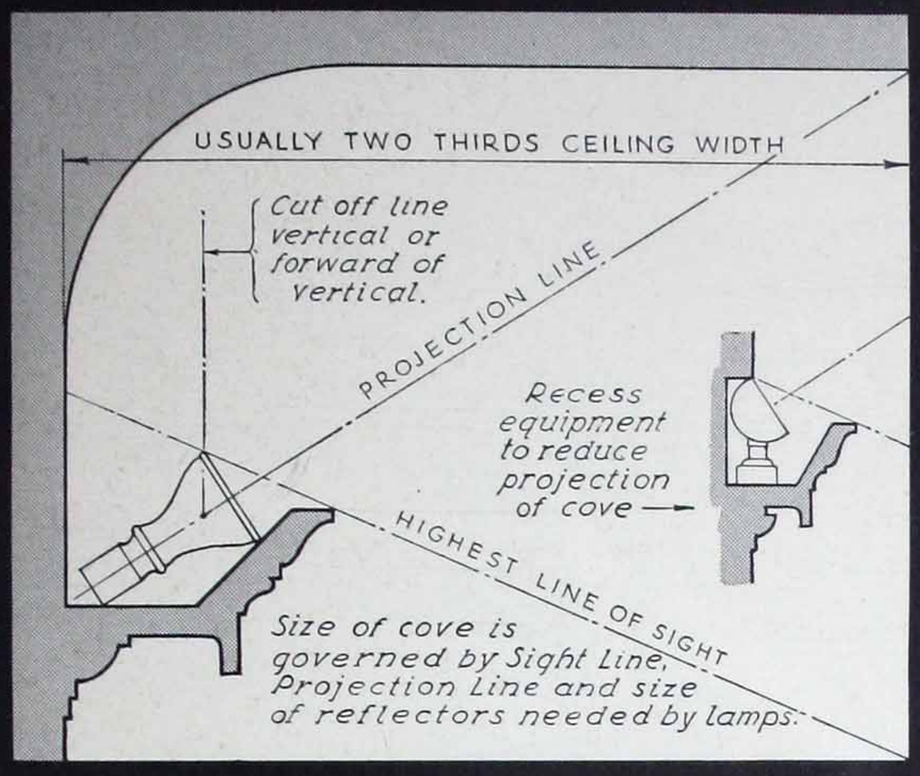
Lighted Niches may be designed in several ways as illustrated in Fig. 2 (Part I) and Table 8. In one, lamps are concealed at one or both sides of the niche behind opaque members. If on both sides the considerations affecting the shape of cove lighted ceilings govern the form of the niche. If on one side only, the niche must be formed to distribute the reflection of the light rays within the niche so as to produce a uniform or graded effect as desired. A niche may also be lighted from below as shown in Fig. 2, or from a suitable soffit light at the head.

Another method places the light source outside of the niche behind an opaque reflector or trough after the manner shown in Fig. 2 for side-wall lighting of fluted surfaces and in Table 8, unit number 2. Backgrounds of niches, which are usually employed for their architectural or decorative value, may be of either diffuse or specularly reflecting material according to the effect desired.

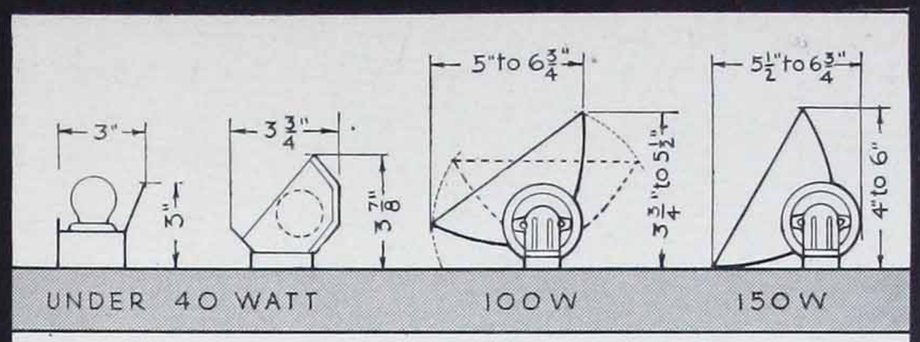
Ceiling Coffers may be lighted as niches or as panels as diagrammatically illustrated in Fig. 2, Part I.

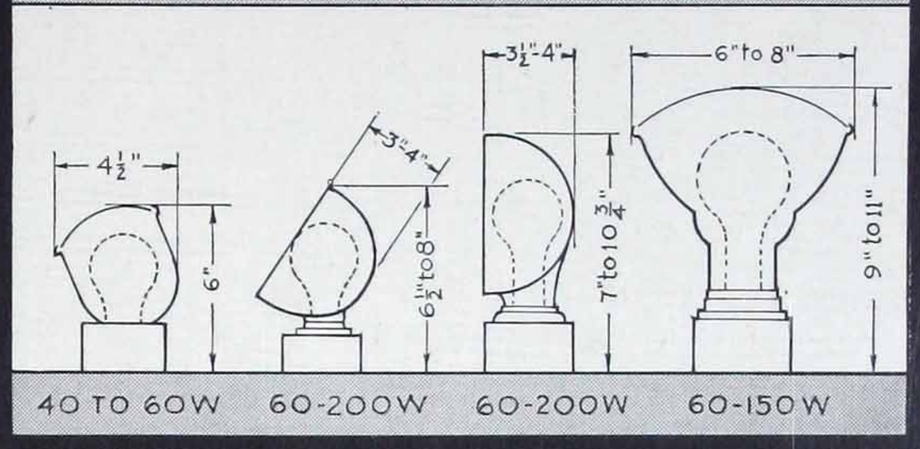
TABLE 3. TRANSMISSION, REFLECTION AND ABSORPTION FACTORS FOR TYPICAL TRANSLUCENT MATERIALS USED IN LIGHTING

Type	Thickness	Transmission	Reflection	Absorption
	Inches	%	%	%
Clear Glass		80-92	8-10	2-10
Clear Glass (Silvered).			82-93	7-18
Configurated, Obscure Clear Glass	.12-.23	57-90	7-24	3-21
Clear Glass:				
Satin Finish:				
—toward source...	.075	89	8	3
—away from source	.075	85-88	6-8	4-9
Acid Etched:				
—toward source...	.08	82-88	7-9	5-10
—away from source	.08	63-78	12-20	10-17
Sandblasted:				
—toward source...	.08-.12	77-81	11-16	7-11
—away from source	.08-.12	70-77	13-18	10-16
Alabaster Glass	.125-.19	60-70	20-30	10
OtherOpalescentGlasses	.09	58-84	13-28	2-14
Marble ($CaCO_3$):				
—one side polished	.29-.39	3-8	30-71	24-65
—impregnated ...	.12-.20	12-40	27-54	11-49
Alabaster ($CaSO_4$):				
—veined	.44-.53	17-30	49-67	14-21
—colored	.25	34-50	27-29	21-39
White Ceramic Coated Clear Glass (varying diffusion)	.125	40-64	24-50	10-13
Flashed Opal Glass:				
Group 1	.08-.11	47-66	31-45	3-10
Group 2	.11-.13	27-35	54-67	8-11
Composition:				
White diffusing	.010-.025	0-41	32-75	7-27
Clear matte (typical sample)	.010	68	15	17
Solid Opal Glass:				
Group 1	.07-.14	12-38	40-66	20-31
Group 2	.07-.10	37-51	43-54	6-11
Group 3	.06-.14	13-35	65-78	4-10

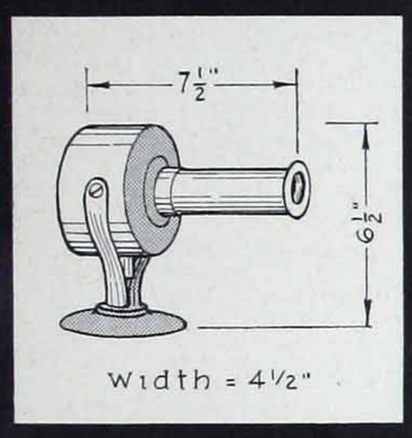


DESIGN OF COVE LIGHTING

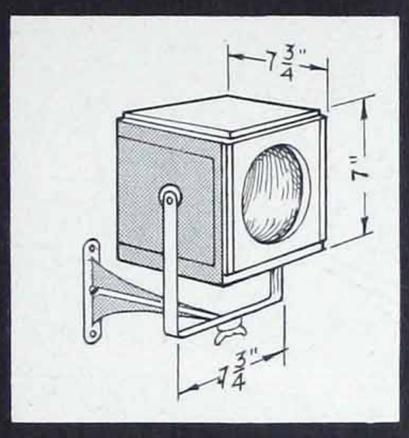




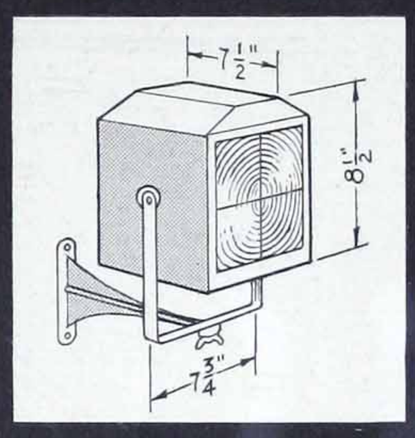
TYPICAL COVE LIGHTING UNITS



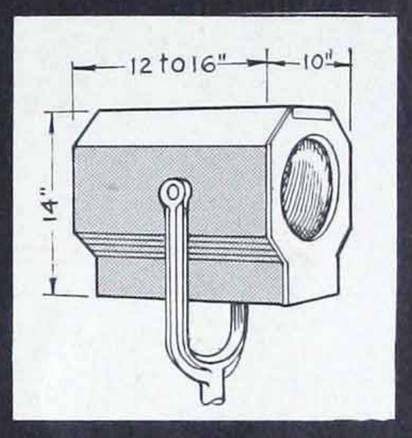
75 and 100 Watts



250 and 1400 Watts

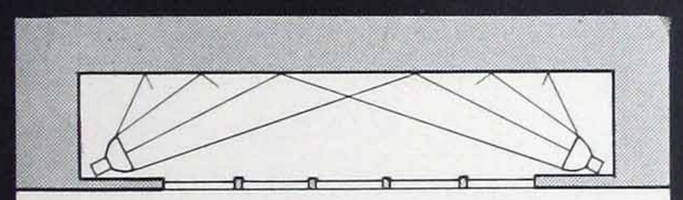


500 Watts

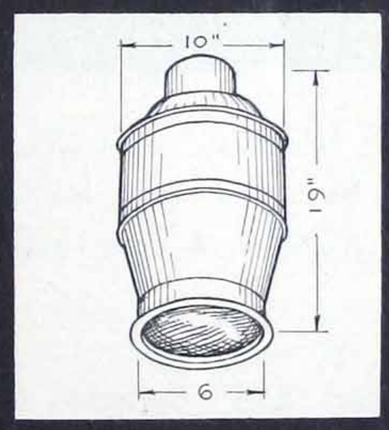


1000 and 2000 Watts

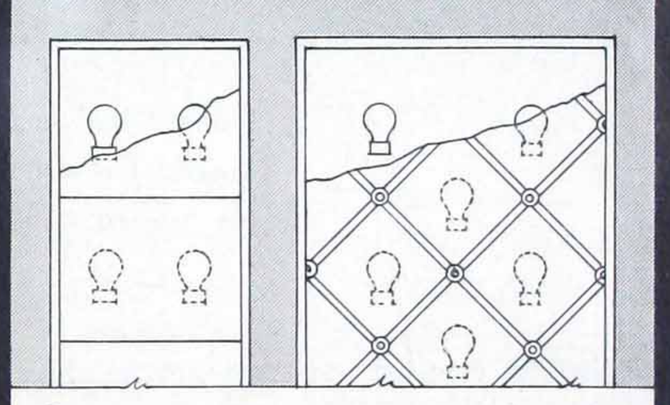
TYPICAL SPOTLIGHTS



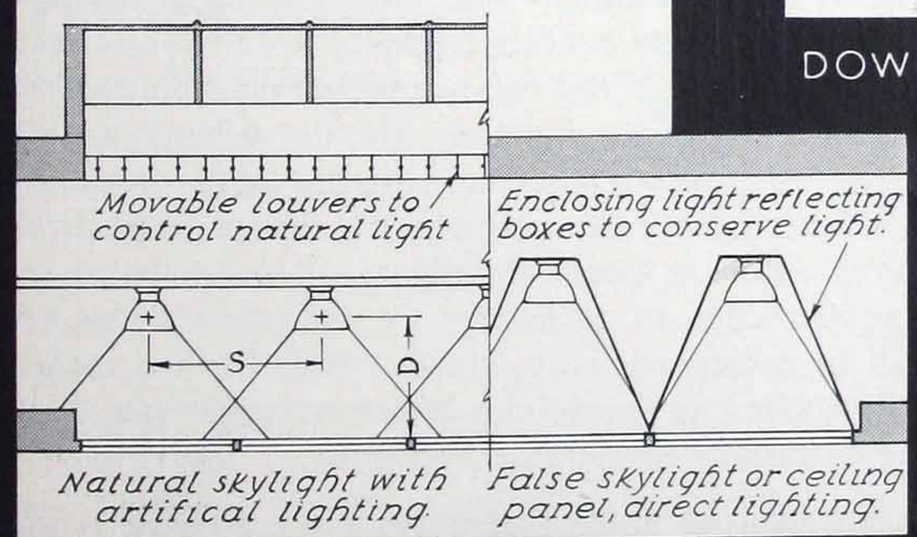
False skylight or ceiling panel indirectly lighted.
Also used for indirect wall panels and false windows.



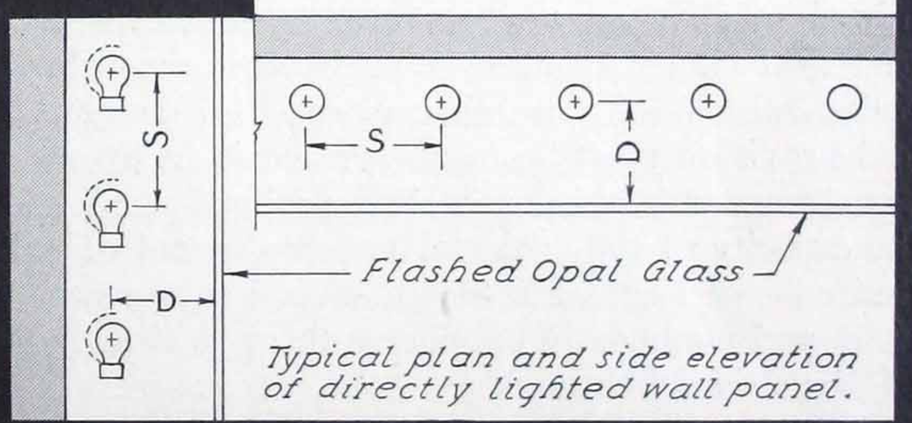
DOWN-LIGHT



Bring glass joints or applied decoration over space between lamps.



SKYLIGHTS AND CEILING PANELS



Typical plan and side elevation of directly lighted wall panel.

DIRECTLY LIGHTED WALL PANELS

Fig. 3. Design details and approximate dimensions of typical built-in light sources



Indirect bed lamp serving twin beds. As a general illuminant it reflects against the wall but may be turned either way for higher intensity lighting toward either side. Wolfgang & Pola Hoffman, interior decorators

Spotlights consist of projectors having lenses and light housings similar to those used in stage work. Since only the lens or an aperture is usually permitted to show on the surface, space adequate to conceal the housings must be provided in the ceilings, walls, false beams or other places of concealment, and provision must be made for access to them for relamping and cleaning. Dimensions depend upon the capacity of the projector and the spread of light desired. In Fig. 3 are shown several representative units and methods of mounting them, with a range of dimensions indicated.

Shielded Ceiling Lights, consisting of direct lighting units projecting their light downward through shields or fixed louvers which prevent the lamp and reflector from being visible at ordinary angles of view, are usually recessed in the ceiling as relatively small circular or polygonal panels. The shields should be so designed as to intercept the minimum amount of light flux. They are generally finished in black to prevent reflection from the sides. Louvers can be arranged if desired in interesting symmetrical geometric forms so that they literally become a part of the decorative scheme. Similar units may be suspended after the manner of direct luminaires and reflectors. Commercially available units range from 6 inches to 18 inches in diameter; those set flush in ceilings usually need a space from 8 inches to 24 inches in depth, the lower wattage lamps, of course, taking the smaller reflectors.

Prismatic-lensed Soffit Lights are commercially available in units of one, two or more light boxes with control lenses 6½, 8½ or 12 inches square. The depth of boxes varies from 4½ to 13 inches depending on the wattage. They are usually recessed in the ceiling or some beam or other horizontal projection. Their lamps are usually adjustable for control of distribution as shown in Fig. 2 (Part 1).

LIGHTING CALCULATIONS

A GENERAL knowledge of how lighting loads are calculated to find the wattage necessary to provide a desired level of illumination is extremely helpful in selecting light sources for a specific project. It is equally valuable in choosing luminaires, fixtures and brackets and as a guide to preliminary design involving built-in units.

The following data are based on procedure used by illuminating engineers, but they are only sufficient for estimating and rough design purposes. The art of lighting involves imponderables that cannot be reduced to rules and formulas. Experience and judgment, often trial and error, have much to do with obtaining a wholly satisfactory result. Advice of a consultant or designing engineer should be secured for final determination and practical design.

The value of these calculations, therefore, lies largely in guiding the architect in making sufficient space provision for built-in units; in determining the number and placing of outlets serving surface or suspended luminaires and fixtures; and in making comparative studies of the electrical load required by different lighting methods to produce equivalent effective lumens.

The method of determining lighting *output* required to produce a desired illumination level is based on the following facts: (1) The full efficiency of a bare lamp can seldom be utilized because of its glare; the almost spherical distribution would waste light where it is not useful and some reflector or diffuser is generally necessary. (2) Each time a beam of light is reflected from a surface (such as a directional reflector, or the walls or ceiling of a room) part of the light is lost by absorption. (3) Each time a beam passes through glass or any other transmitting or diffusing medium (such as a lens or an enclosing globe) more light is absorbed or lost by reflection. (4) All lighting sources gradually depreciate in transmitting or reflecting capacity unless constantly cleaned or renewed, and there is a gradual loss of output from lamps due to ageing.

Therefore, to get a given quantity of light at any point it is necessary to add to the theoretical light output, allowances for (a) loss in the luminaire, panel or fixture, (b) loss due to absorption of light by room surfaces and furnishings, and (c) depreciation. The sum of these allowances added to the flux required on the work gives the actual output needed from the lamps.

Another factor influencing design is the relative efficiency of lamps of different types and sizes. In general, a single lamp of relatively high wattage produces more light than two or more lamps of the same total wattage. That is: a 500-watt lamp will give more light than five 100-watt lamps. Thus when large luminaires are used, permitting the employment of single lamps in each source, somewhat higher output per watt can be anticipated in comparison with cove lighting or panel lighting, where space restrictions or the need for uniformity usually require the use of small lamps in greater number.

Procedure in estimating lighting loads can follow either of two methods. The first, employed by illuminating engineers on important projects, or for checking preliminary estimates, requires the calculation of each source of loss separately from test data and a complete knowledge of room conditions. The second, presented here, is a short cut *estimating* method (also used by illuminating engineers for preliminary design purposes) which uses experience tables that combine all the factors involved and vastly simplify the work. After approximate loads are found by this short cut method the designer is in a position to study the individual light sources he will employ and to modify his rough estimates according to his final selections.

RULE 1 . . . To find the illumination level required in any room: Select from Table 4 a general lighting level in foot-candles appropriate to the purpose or occupancy of the room. These are recommended levels for average visual conditions but may be increased wherever superior results are desired. If two or more levels are desired to vary general lighting according to mood or changes in occupancy, each of the following steps should be repeated for each lighting intensity and the light sources so divided among separately controlled circuits and so distributed throughout the room as to give the desired effect when any single level is in use. General lighting of a room is computed independently of local high intensity lighting of special areas, and usually without regard for the output of purely decorative sources.

Where desks, work benches, machines, speaking rostrums or other specific areas require relatively high level local lighting, select higher illumination levels from Table 4 which are nearest in character to the local lighting problems at hand. In the case of residence interiors this table shows local lighting levels as well as some general lighting levels. Use these data for determining the required output of local sources, either independently of general lighting or supplementary to it, according to the needs of the project.

It is difficult to specify lighting levels in a residence with the same degree of accuracy as in offices and commercial establishments because of the varying personal tastes and a general lack of experience on the part of home owners with the

TABLE 4 . . . RECOMMENDED ILLUMINATION LEVELS

Type of Space	Foot-candles Recommended
ARMORIES	
Drill Sheds	5-10
Exhibition Halls	10-20
ART GALLERIES	
General	2-5
On Paintings	25-100
AUDITORIUMS	2-5
AUTOMOBILE SHOW ROOMS	10-20
BANK	
Lobby	5-10
Cages and Offices	10-20
BARBER SHOP	10-20
BASKET BALL	10-20
BOWLING	
On Alley, Runway, and Seats	5-10
On Pins	30-50
BILLIARDS	
General	5-10
On Tables	30-50
CHURCHES	
Auditorium	2-5
Sunday School Room	5-10
Pulpit & Rostrum	10-20
CLUB ROOMS	
Lounge	2-5
Reading Room	10-20
COURT ROOMS	5-10
DANCE HALLS	2-5
DENTAL OFFICES	
Waiting Room	5-10
Operating Office	10-20
Dental Chair	30-50
DRAFTING ROOM	30-50
ELEVATOR—Freight and Passenger	2-5
FIRE ENGINE HOUSE	
When Alarm is Turned in	5-10
At Other Times	1-2
GARAGE—Automobiles	
Storage—Dead	1-2
Storage—Live	5-10
Repair Dept. and Washing	10-20
GYMNASIUMS	
Main Exercising Floor	10-20
Swimming Pool	5-10
Shower Room	5-10
Locker Room	2-5
Fencing, Boxing, Wrestling	10-20
HALLS, PASSAGEWAYS	2-5
HANDBALL	20-30
HOSPITALS	
Lobby and Reception Room	2-5
Corridors	1-2
Wards (with Local Illumination)	2-5
Private Rooms	5-10
Night Illumination	0.1-0.2
Operating Table	200-500
Operating Room	10-20
Laboratories	10-20
HOTELS	
Lobby	5-10
Dining Room	2-5
Kitchen	10-20
Bedrooms	5-10
Corridors	1-2
Writing Room (on Desks)	10-20
LIBRARIES	
Reading Rooms (on Tables)	10-20
Stack Room	5-10
LODGE ROOMS	5-10
LUNCH ROOM	5-10
MARKET	10-20
MOTION PICTURE THEATERS	
During Intermission	2-5
During Pictures	0.1-0.2
MUSEUM	
General	5-10
Special Exhibits	25-100
OFFICE BUILDINGS	
Private and General Offices	
Close Work	20-30
No Close Work	10-20
File Room	5-10
Reception Room	5-10
Corridors and Stairways	2-5
Vault	5-10
POST OFFICE	
Lobby	5-10
Work Room	
Sorting, Mailing, etc.	10-20
Storage	5-10
Private and General Offices	10-20
File Room and Vault	5-10
TRANSPORTATION	
Depot—Waiting Room	5-10
Ticket Offices	10-20
Rest Room—Smoking Room	5-10
Baggage Room—	
Checking Office	10-20
Storage	5-10
Concourse	2-5
Train Platform	1-2
RESTAURANTS	5-10
RACQUET	20-30
SCHOOLS	
Auditorium	5-10
Class Rooms, Library and Office	10-20
Corridors and Stairways	2-5
Drawing	20-50
Laboratories	10-20
Manual Training	10-20
Sewing Room	20-50
Study Rooms	
Desks	10-20
Blackboards	10-20
SHOWCASES	(Two to four times that of the store proper)
SHOW WINDOWS	
Large Cities—	
Brightly Lighted Districts	100-200
Secondary Business Locations	50-100
Neighborhood Stores	30-50
Medium Cities	
Brightly Lighted Districts	50-100
Neighborhood Stores	30-50
Small Cities and Towns	30-50
Lighting to Reduce Daylight Reflections	200-1000
SKATING RINK (Indoor)	5-10
SQUASH	20-30
STORES	
Large Specialty and Department Stores—	
Main Floors	10-20
Other Floors	10-15
Basement Store	10-20
Small Stores	
Furniture	5-10
Furrier	20-30
Piano	5-10
All Others	10-20
TELEPHONE EXCHANGE	
Operating Rooms	5-10
Terminal Rooms	10-20
Cable Vaults	5-10
TENNIS (Indoor)	30-50
THEATRES	
Auditorium	2-5
Foyer	5-10
Lobby	10-20
TOILET AND WASHROOMS	5-10

RESIDENCE INTERIORS

GENERAL AND LOCAL LIGHTING

READING	
Ordinary type	10-20
Prolonged periods with fine type	20-50
SEWING	
Ordinary sewing on light goods	10-20
Prolonged sewing on light goods	20-50
Prolonged average sewing	50-100
Fine needlework, sewing on dark goods	100 or more
DINING ROOM	
When used for reading or writing	10-20
KITCHEN	
General	5-10
Work Counters, Sink	10-20
BEDROOM	
General	2-5
Bed Light	10-20
Dresser, Vanity and Dressing Table Mirrors	10-30
Sewing Machine	20-50
BATHROOM	
At mirror	10-30
RECREATION ROOM	
General	5-10
Local	10-20
Work Bench	10-30
LAUNDRY	
Tubs, Ironing Machine, Ironing Board	10-20
STAIRWAYS	2-5
MISCELLANEOUS	
Card Playing	5-10
Writing	10-20
Children's Study Table	20-50

TABLE 5—ROOM AND MAINTENANCE CONDITIONS

PROPORTIONS OF ROOM	COLOR OF CEILING AND UPPER SIDE WALLS	CONDITIONS FACTORS			
		Direct Lighting Luminaires, downward reflectors, panels, recesses, luminous projecting elements		Indirect and Semi-Indirect Lighting Luminaires, pendent and free standing reflectors, coves	
		MAINTENANCE OF EQUIPMENT			
		Very Good	Fair	Very Good	Fair
Width Approximately Four or More Times Ceiling Height	Light Medium Dark	Favorable Favorable Favorable	Favorable Favorable Average	Favorable Favorable Unfavorable	Favorable Average Unfavorable
Width Approximately Twice Ceiling Height	Light Medium Dark	Favorable Favorable Average	Average Average Unfavorable	Favorable Average Unfavorable	Average Unfavorable Impracticable
Width Approximately Equal to Ceiling Height	Light Medium Dark	Average Unfavorable Unfavorable	Unfavorable Unfavorable Unfavorable	Average Unfavorable Unfavorable	Unfavorable Impracticable Impracticable

benefits of modern lighting. Data are available, however, regarding the lighting requirements for most of the processes or work carried on in the home. The data contained in Table 4 on residence lighting are approved by the Residential Lighting Committee of the Illuminating Engineering Society. Most of these higher levels of illumination are obtained through the use of local light sources of one sort or another. Architects can do much to facilitate the adoption of better lighting in residences by encouraging the installation of modern types of fixtures or built-in light sources (or both), under the architect's supervision, which meet the standards of good lighting established herein.

In any event, it is the architect's responsibility to provide outlets for general illumination of both ceiling and wall type (even though capped for the present until the owner learns the value of general lighting from such sources); to provide a liberal supply of convenience outlets for portable lamps; and to provide suitable switching control and adequate wiring throughout the dwelling.

In any type of building where special lighting of areas such as murals, statuary, paintings or other architectural features are desired for design emphasis primarily, it is permissible to adopt a local lighting level from two to ten times the general lighting level.

TABLE 6—APPROXIMATE FOOT-CANDLES DELIVERED

By the Use of 1 Watt per Square Foot of Floor Area

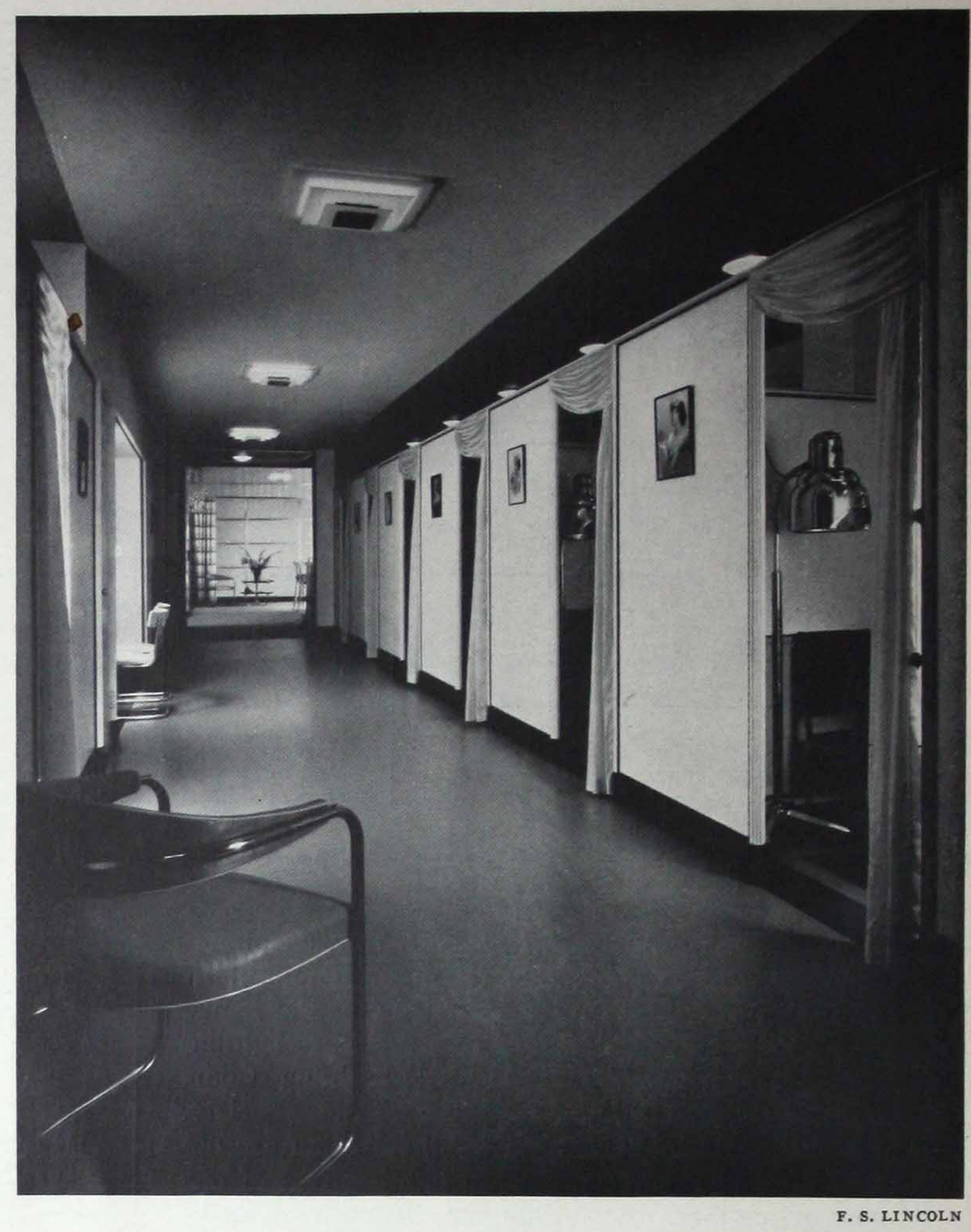
TYPE OF LIGHT SOURCE	ROOM CONDITIONS		
	Favorable	Average	Unfavorable
Direct Lighting			
Mirrored reflector or R. L. M. dome	6.0 - 7.5	5.0 - 6.0	4.0 - 5.0
Enclosing globes	4.5 - 6.0	3.0 - 4.0	2.2 - 2.5
Panels, recesses and luminous projecting elements	3.5 - 5.0	2.5 - 4.0	2.0 - 3.0
Semi-Indirect Lighting	3.5 - 5.0	2.5 - 3.5	1.7 - 2.5
Indirect Lighting			
Pendent or free-standing reflectors	2.5 - 4.0	1.5 - 2.5	1.2 - 1.5
Coves	2.2 - 3.5	1.2 - 2.2	1.0 - 1.2

ROOM CONDITIONS

AS noted previously, the shape, proportions and color treatment of a room affect its lighting "qualities" and those qualities in turn vary according to the type of light source employed. Maintenance conditions, involving presence or absence of dust and soot in the atmosphere, and the frequency of cleaning lamps and fixtures further affect lighting operate. Their combined effect is expressed as the room conditions under which the light source will operate. Their combined effect is expressed as the "conditions factor" of the room, not in numerical terms but relatively as "favorable," "average" and "unfavorable."



BROWNING STUDIOS



F. S. LINCOLN

Above: Three types of lighting are used in this display room of Stroheim & Romann, New York, designed by Eugene Schoen, architect. Note in upper left a wall box illuminating the ceiling, at rear of corridor prismatic lens boxes concentrating illumination on focal feature, display racks at either side strongly lighted by downward reflectors with spill shields.

At right: In the Robert Beauty Salon, Scott & Teegen, architects, have used luminous ceiling fixtures in the corridor, downward direct lighting of recessed reflectors over each hairdressing booth, and a brightly illuminated mirror in recess at left.

RULE 2 . . . To find the conditions factor of a given room: Refer to Table 5, "Room and Maintenance Conditions" and select the appropriate conditions factor. The proportions of the room are self-explanatory. The color of ceilings and upper side walls may be judged from Reflection Factors given in Table 2 (Part I) as follows: "Light" normally would represent a ceiling reflectivity of 70% or better combined with side walls reflecting from 10% to 50% or both ceiling and side walls reflecting 50%. "Medium" connotes a ceiling factor averaging 50% with side walls from 10% to 50%. "Dark" connotes a ceiling reflecting about 30% and side walls reflecting from 10% to 30%. Maintenance of equipment may be classed as very good if the air is comparatively free of dust or soot and the light sources are cleaned at frequent and regular intervals. Fair maintenance implies less frequent cleaning and perhaps less freedom from dust and soot in the air.

RULE 3 . . . To estimate the wattage required to produce a selected illumination level for general lighting: Table 6 shows the approximate foot-candles delivered by principal types of light sources by the use of one watt per square foot of floor area. Find in this table the foot-candles data appropriate to the room conditions and to the type of light source employed. Divide the desired level of illumination in foot-candles by the foot-candles produced by one watt per square foot. This will give the equivalent watts per square foot needed to provide the required amount of light. Multiply by the area of the room in square feet to obtain an approximate indication of the total wattage needed in the room, using the selected type of lighting.

Example 1. Consider a reception room 15′ x 30′ in plan with a 10′ ceiling of white plaster and cream tinted walls, that is to be lighted to five foot-candles by cove lighting under fair maintenance conditions. The room conditions factor found in Table 5 is "average." From Table 6 it will be found that one watt per square foot will deliver 1.2 to 2.2 foot-candles. The room has an area of 450 sq. ft.; hence the calculation is $5 \div 1.2 = 4.166$ watts $\times$ 450 sq. ft. $=$ 1875 watts. A similar calculation, using the higher value (2.2) from Table 6, indicates a load of 1025 watts. This lower value would be





Left: Show and display room of Socony Vacuum Corp., New York, employs an indirect ceiling trough, a cornice band of structural glass blocks illuminated from behind, and showcase lighting including high voltage gaseous filled tubes for luminous signs. Irving Schwarcz, Inc., New York, Decorators.

Above: Board of directors room, General Electric Company, New York, is lighted by a luminous trough suspended from the ceiling, containing lumiline lamps for semi-indirect lighting and corner brackets of similar character to balance light distribution. Shreve, Lamb & Harmon, architects.

required if large lamps and high efficiency reflectors could be employed; the higher load would be needed if the lamps to be used were small and the cove reflecting surface of relatively low efficiency.

Example 2. An entrance lobby in an office building measures 30′ x 50′ and has a 30′ ceiling of light color. Its lower walls are wainscoted with gray marble to 10 ft. above the floor and the upper walls are painted light gray. It is proposed to use some form of downwardly directed lights in the ceiling and to install a cove at the wainscot level to illuminate the upper side walls and ceiling enough to cross-light these areas. A general lighting level of eight foot-candles is required. The room conditions factor from Table 5 is "unfavorable" for both direct and indirect methods, assuming very good maintenance.

Table 6 shows that one watt per square foot will provide 4.0 to 5.0 foot-candles from direct downward reflectors and 1.0 to 1.2 foot-candles from coves. It may be tentatively assumed that six of the eight foot-candles required may come from ceiling lights and the remaining two from the coves. The area being 1500 sq. ft. the calculations for direct lighting are: $6 \div 4 \times 1500 = 2250$ watts, or $6 \div 5 \times 1500 = 1800$ watts. The calculations for the indirect lighting are $2 \div 1 \times 1500 = 3000$ watts or $2 \div 1.2 \times 1500 = 2500$ watts required in the coves.

The wide spread between minimum and maximum wattages shown in both examples must be reconciled by exercise of judgment and knowledge of the relative efficiencies of the light sources from which a selection is made. High efficiency units with large lamps require the lower wattage; low efficiency units and use of multiple lamps of small size require maximum wattage. This wide spread also indicates the limitations of this estimating method.

Obviously, these calculations also show there is distinct economy in the use of the very best equipment available. Initial savings possible through the purchase of cheaply made reflectors, luminaires or luminous panels or boxes are soon offset by the higher current consumption they require. Since light sources are installed but once, yet operate many hours a year for many years and require maintenance and cleaning at frequent intervals, the selection of equipment warrants great care.



PEYSER & PATZIG



Above: New Weber & Heilbroner store, 550 Fifth Avenue, New York, employs cove reflectors over the side-wall showcases brightly illuminating the side walls and providing general illumination of the ceiling. Solid letter signs are silhouetted against the lighted walls. Downward reflectors in ceiling with black painted spill shields give high intensity illumination on the showcases which will require no other case lighting. Column and ceiling dome at rear lighted from reflectors concealed in case surrounding the column. Designed by Grand Rapids Store Equipment Company.

At right: Living room in residence of G. N. Stieff, Baltimore, has general lighting from cove troughs of special design containing four circuits, two white, one amber and one rose. These are controlled by motor operated dimmers with remote momentary contact push buttons in living room which permit automatic control of lighting level and color. Recessed prismatic light box in ceiling provides special lighting for portrait. James S. Nussear, Jr., architect.

DISTRIBUTION OF LIGHT SOURCES

HAVING thus determined the total wattage required by a room, it remains to divide the wattage between the various light sources to be employed, in such a way as to give satisfactory distribution.

Data on the spacing and suspension height of direct, semi-indirect and indirect luminaires should be obtained from the manufacturers of such units or from standard handbooks. Given the total wattage required, the ceiling height or suspension height available, the number of outlets that can be employed and the distribution curves of various luminaires, it is possible to select units of suitable size and type to meet all requirements of good lighting and good appearance.

Selection of "fixtures" meeting modern lighting standards may proceed on the same basis, by classifying the type of unit as either direct, semi-direct or indirect and by obtaining from the manufacturer approximate data on the light output and distribution characteristics of the fixture. If the latter are not obtainable, reduce the lamp output in lumens by the estimated loss in the fixture, using Tables II and III

The problem of distributing light by the use of panels, coffers, niches, luminous beams and cornices, and similar built-in areas presenting fairly extensive lighted surfaces to the vision, is somewhat more complex. The brightness of the source must be considered in relation to its position, the purpose of the room and the general lighting level.

BRIGHTNESS OF LUMINOUS SOURCES

THE position of the luminous source governs the permissible brightness approximately as given below. These values are based on somewhat limited experience and are for well lighted rooms.

Projecting ceiling elements, 20 feet or more above the floor	500 foot-lamberts
Projecting elements on low ceilings, particularly in large rooms	250 foot-lamberts
Same, for mezzanines	175 to 225 foot-lamberts
Wall panels or recesses in passageways	200 foot-lamberts
Wall panels and niches in places of business where they are not directly in the usual line of sight	125 foot-lamberts
Decorative panels constantly in field of view	75 foot-lamberts

As the area of luminous surfaces is increased, the maximum desirable brightness is lowered, for glare depends in part upon the total amount of light directed toward the eye. The length of time the condition is encountered is another factor; greater brightness being permissible in lobbies, corridors and passageways than where people remain in one place for long periods.

The angle of view is important, as a luminous surface fore-shortened by its relation to the eye appears less bright than one normal to the line of vision. Hence a flush ceiling panel or a soffit light appears less bright than a luminous beam or cornice, or a wall panel having the same actual brightness.

Background contrast affects eye comfort and apparent brightness. A luminous source appears brighter on a dark background than on a light surface, and the effect of glare becomes troublesome if the contrast is severe. The eye can tolerate sources of greater brightness in light surroundings than when the source is seen against dark hangings, walls, or ceiling. Glare from a unit of constant brightness is lessened as the general illumination level is increased; but multiplying the amount of light in a room by 10 only makes it permissible to double the brightness of the luminous units. In decorative units the brightness may range to very low values.

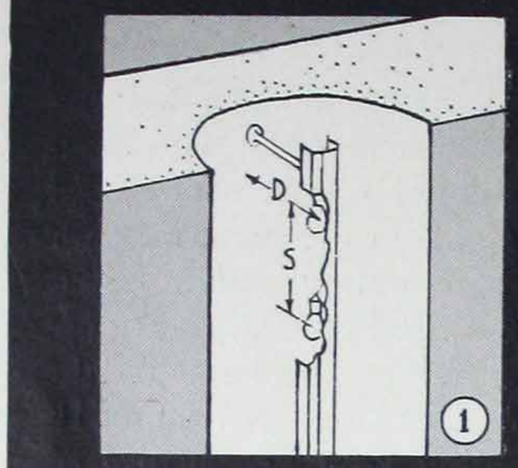
Brightness Calculations are based on the definition of the foot-lambert, which is a "unit of brightness of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square foot." Where the brightness of a luminous unit cannot be obtained from the manufacturer (as in the case of a specially designed panel) the following rule may be used to compute the approximate brightness.

RULE 4 . . . To find the brightness of a luminous element in foot-lamberts:

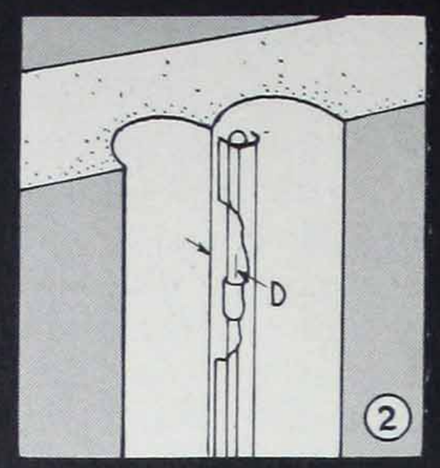
(1)—Compute the area in square feet of the luminous element (such as a panel, niche, project-

TABLE 7 . . . LUMINOUS FLUX
EMITTED BY STANDARD MAZDA LAMPS

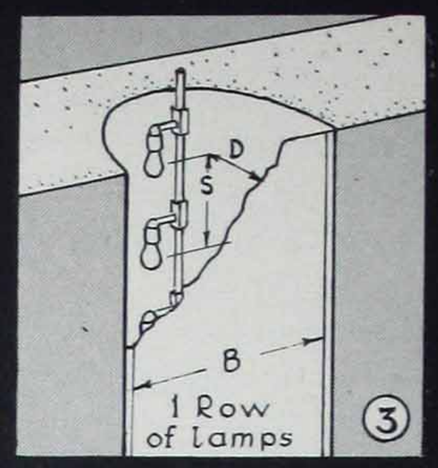
Watts	Lumens	Watts	Lumens
15	140	150	2,400
25	250	200	3,400
40	430	300	5,490
50	580	500	9,800
60	750	750	14,550
75	1,030	1,000	20,700
100	1,510	1,500	33,000



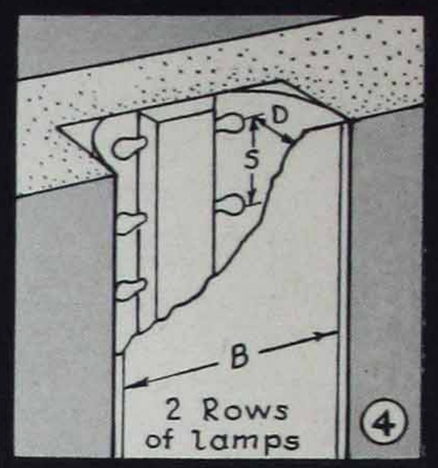
Half Cylinder Recess



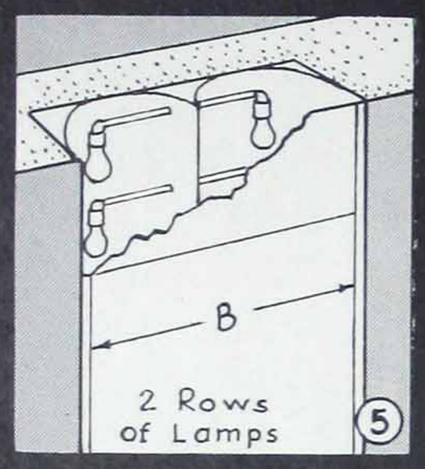
Double Recess



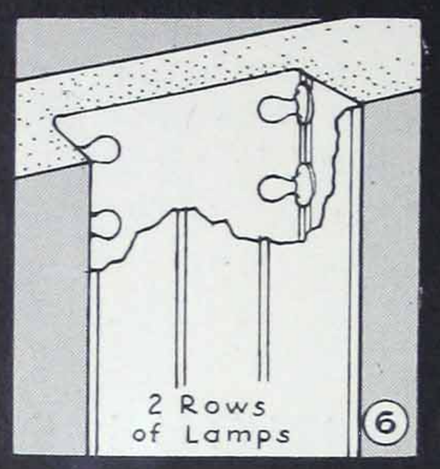
Flush Panel



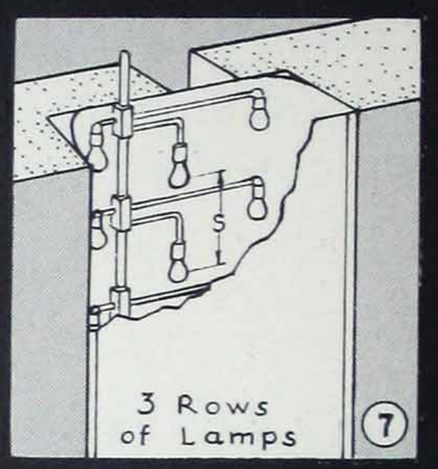
Flush Panel



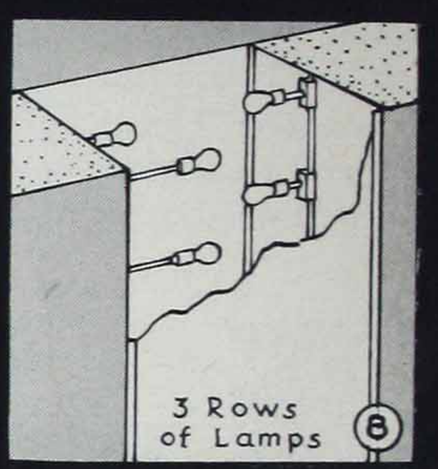
Flush Panel



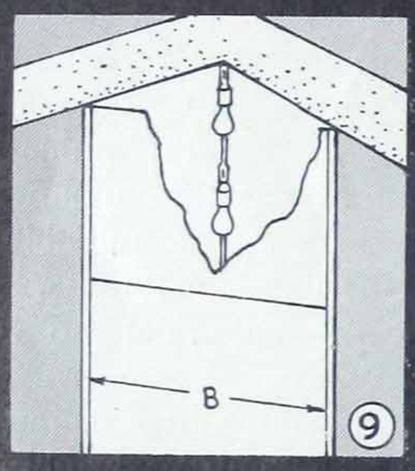
Flush Panel



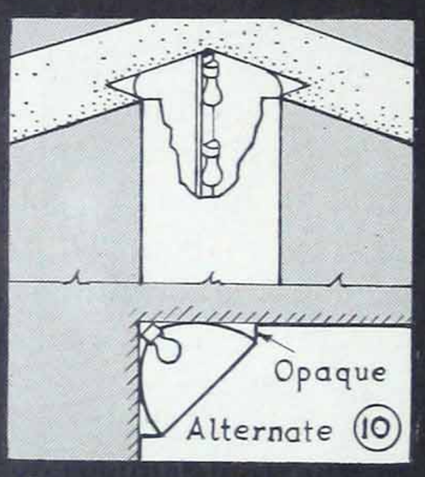
Flush Panel



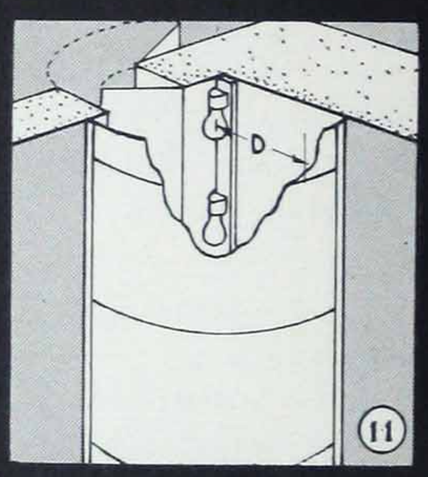
Double Window



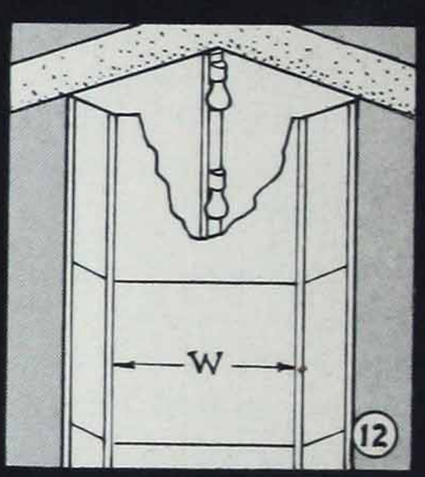
Corner Panel



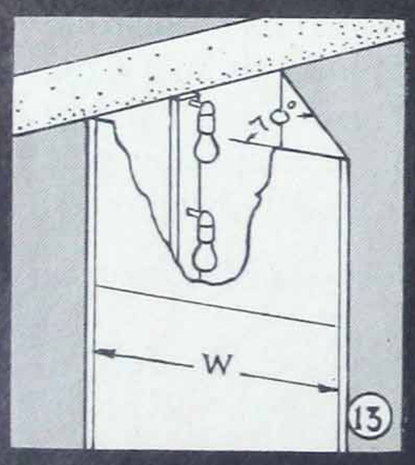
Corner Panel With Reflector



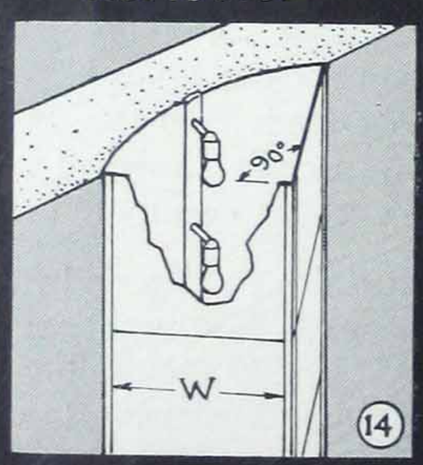
Quarter Cylinder



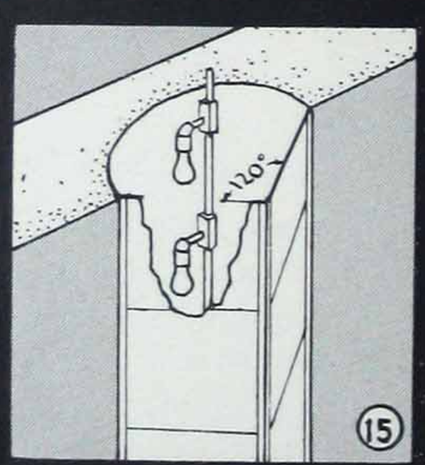
Projecting Element



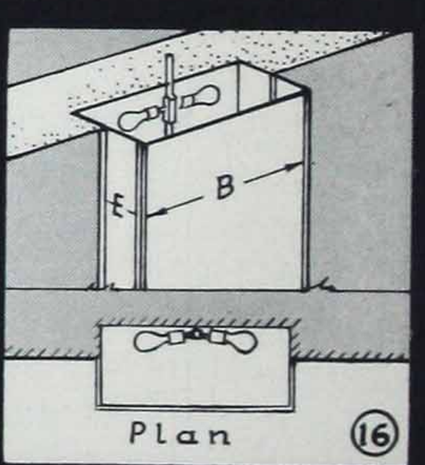
Projecting Element 70°



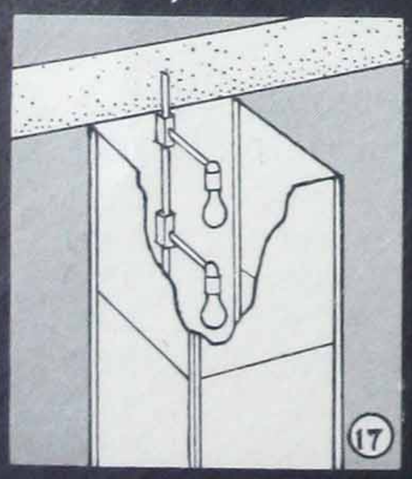
Projecting Element 90°



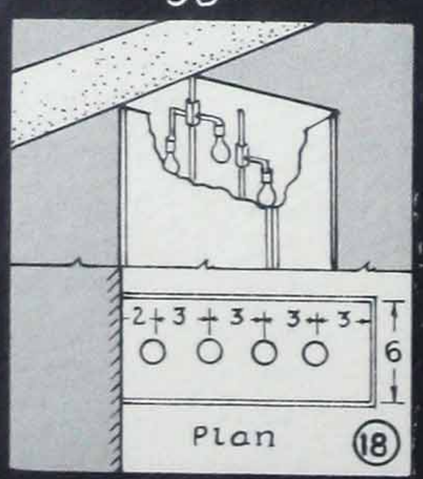
Projecting Element 120°



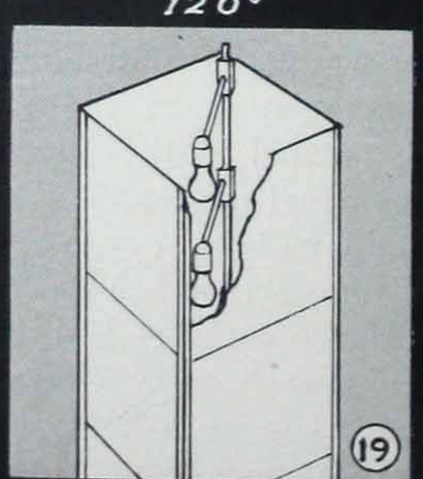
Shallow Projecting Element



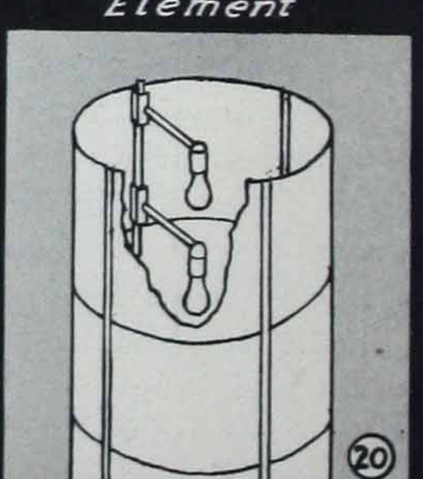
Square Projection



Deep Projection



Square Column



Cylinder

LUMINOUS ARCHITECTURAL ELEMENTS (SEE TABLE 8)

TABLE 8. EFFICIENCY OF LUMINOUS ARCHITECTURAL ELEMENTS
(Per Cent of Total Lumens Emitted by Test Units Shown in Diagram at Left)

Unit No.	Width Tested (inches) (B)	Spacing of Lamps (S)	Distance Lamps to Glass (D)	Efficiency (% of lamp lumens)					Notes
				Open	Flashed Opal	Solid Opal No. 1	Compo-sition	Solid Opal No. 2	
1	25	1.9D		43	..	..	..	..	For surface of 0.75 Reflection Factor; for other surfaces = 0.52 x Reflection Factor
2	25	1¾ in.		39	..	..	..	..	For surface of 0.75 Reflection Factor; for other surfaces = 0.57 x Reflection Factor
3	12	1.5D	0.67B	..	49	34	27	18	For rectangular back, use 0.95 of Efficiency values given
4	24	1.5D	0.33B	..	51	37	29	22	Row spacing is ½ of panel width
5	24	1.2D	0.27B	..	49	34	27	20	This form of reflector, with lamp rows spaced ⅔ of panel width, produces desired transverse uniformity with shallow cavity
6	24	1.2D	0.27B	..	49 (including ground glass panel)				Lamps centered on flashed opal panels. Some spottiness when viewed at angle
7	24	1.25D	0.27B	..	49	34	27	20	
8	24	D	0.33B	..	65	48	38	29	Efficiency of two faces
9	20	1.5D	0.4B	..	54	38	30	23	Spacing ratio applies for longitudinal uniformity. Brightness fades off from center to sides
10	10½	1.5D	0.67B	..	41	29	23	17	Transverse uniformity is attained in the narrow panel
11		1.5D	9 in.	..	57	41	31	25	For half cylinder, see data of Fig. 13
12	W=16	1.5D	0.67W	.	54	38	30	23	
13	W=13	1.5D		..	76	57	43	39	For half cylinder, use 1.05 times above Efficiency
14	W=14	1.5D	0.5W	..	65	46	36	32	The lamps should be equidistant from and centered behind the sides
15	W=11½	1.5D	0.67W	..	57	41	31	28	The lamps should be equidistant from and centered behind the sides
16	24	1.4D	0.37B	..	63	46	36	27	Projection E = 0.25B. Lamps located behind plane of wall about ½ E
17	12	1.5D		..	74	56	44	40	
18	12	1.1D	(3 rows)	..	65	48	38	29	
19	12	1.4D		..	83	67	53	45	Framing to conceal wiring
20	Dia=12	1.4D		..	87	71	58	50	Conduit riser located on least conspicuous side

Construction of Test Units: Reflector or cavity surfaces of 75% reflection factor, matte white; wiring devices painted same as background. Framing ½ inch wide. Lamp axes parallel to plane of glass. Transmission factors of glasses used: Flashed opal glass, 50%; Solid opal glass, No. 1, 32%; Composition (0.01 inch thick), 23%; Solid opal glass, No. 2, 18%.

ing light box or cornice, etc.) and determine the number and size of lamps to be used therein.

(2)—From Table 7 find the luminous flux emitted by the lamps to be used, in lumens. Compute the total lumens emitted within the unit.

In Table 8 and its accompanying diagrams find the type of luminous element corresponding most nearly to the unit under consideration and take the efficiency in per cent for the appropriate translucent material. Multiply the total lumens emitted within the unit by the efficiency percentage to get the approximate light output of the unit in lumens.

(3)—Divide this net output in lumens by the square feet of luminous surface (1) to arrive at the average brightness in foot-lamberts.

If the brightness exceeds that permissible for the location of the luminous element, its size may be increased without increasing the total wattage utilized.

The importance of these brightness calculations to the architect will be obvious when skylights, panels or other luminous areas are used as direct light sources. Rule 3 and Table 6 may be used to estimate the wattage needed with such light sources. But how large they must be and how they should be distributed in the room can only be determined by establishing the permissible brightness as here described.

In general, when these luminous sources are used to produce uniform distribution of light throughout a room they should be ceiling units; as side wall

panels, unless high on the walls, give fairly high level lighting on adjacent horizontal surfaces, but the more remote areas are less effectively lighted. Vertical surfaces, however, are well lighted by wall panels. Furthermore, such luminous sources should be distributed throughout the room in proportion to the light desired in each part, as it is undesirable to have some elements brighter than others.

WIRING AND CONTROL EQUIPMENT

IN all lighting calculations, it is assumed that the lamps used are to be operated at their rated voltage. In actual practice this only occurs when the wiring to these outlets has been designed to minimize voltage drop by sizing the wires employed in proper relationship to the length of the circuits. The importance of this feature cannot be over-emphasized; the calculations are based on the assumption that the voltage at the socket is that marked on the lamps. If a 120-volt lamp receives only 115 volts it will deliver but 86% of its rated light output. This subject is discussed in detail in AMERICAN ARCHITECT "Reference Data No. 8—Electrical Wiring Materials"—November, 1933, to which the reader is referred for data based upon "Minimum Specifications for Adequate Wiring of Lighting Circuits" in various types of buildings. An indication of the wire sizes required to serve lighting circuits is given in Table 9, which is based on a 2% maximum voltage drop on 110-volt, two-wire circuits. The new minimum standards recommend 1½% voltage drop as maximum and the use of no wire smaller than No. 12, but the data in Table 9 are commonly used in wiring calculations.

Control of Lighting Circuits is an important part of the architect's problem, for the modern use of light demands convenience of use as well as adequate levels of illumination. Individual light sources or logical groups of luminaires requiring not over one circuit are usually controlled from wall switches placed at a convenient control point. Where several circuits are subject to control from the same point, these switches are either assembled in gangs or mounted in enclosing panel boxes. Three-level lighting using two-filament lamps may be controlled by combination switches consisting of two tumbler switches assembled in the same box. One tumbler controls the smaller filament, the other the high wattage filament, and both are operated together for maximum lighting. Three-circuit electrolier switches may also be adapted to this purpose.

Where large groups of lights involving several circuits are controlled at the same time, it may be most economical to employ a remote control switch placed wherever wiring economy dictates, which is operated in turn by a momentary contact button at the point of most convenient access. The use of remote control switches makes it unnecessary to carry large wire sizes to wall switches, thereby often saving more than the cost of the remote control apparatus in materials and line losses.

Automatic control of light has been made possible by the development of photo-electric cell relay equipment which responds to prevailing illumination in any given space. This light sensitive element will turn on artificial lights wherever natural lighting diminishes below the desired minimum level of illumination. The lights remain on until turned off manually or by a time switch, or until natural light increases the level of illumination sufficiently to dispense with the artificial sources.

Where graduated illumination is required as in auditoriums, dance halls, theatres, etc., it is preferable to use alternating current and reactance dimming because it is much more efficient than old style resistance dimming. The new thyratron control combined with reactors permits the most delicate effects and the finest graduations.

TABLE 9 . . . BRANCH CIRCUIT AND FEEDER WIRE SIZES FOR VARIOUS LENGTHS OF RUN

Wattage Load 115 Volt Circuit	Amp. Load	LENGTH OF RUN IN FEET 30	40	50	60	70	80	90	100	120	140	160	180	200
575	5	14	14	14	14	14	14	12	12	12	10	10	10	10
690	6	14	14	14	14	14	12	12	12	10	10	10	8	8
805	7	14	14	14	14	12	12	12	10	10	10	8	8	8
920	8	14	14	14	12	12	12	10	10	10	8	8	8	8
1,035	9	14	14	12	12	12	10	10	10	8	8	8	8	6
1,150	10	14	14	12	12	10	10	10	10	8	8	8	6	6
1,380	12	14	12	12	10	10	10	8	8	8	8	6	6	6
1,610	14	14	12	10	10	10	8	8	8	6	6	6	6	4
1,840	16	12	12	10	10	8	8	8	8	6	6	6	4	4
2,070	18	12	10	10	8	8	8	8	6	6	6	4	4	4
2,300	20	12	10	10	8	8	8	6	6	6	4	4	4	4
2,875	25	10	10	8	8	6	6	6	6	4	4	4	2	2
3,450	30	8	8	8	6	6	6	6	4	4	4	2	2	2

NOTE: This table is based on 2% loss in voltage on 110-volt, 2-wire circuits, or 1% loss on 220-volt 2-wire and 110/220-volt, 3-wire circuits. For good voltage regulation design feeders for a maximum of one per cent voltage drop, branch circuits for a maximum of two per cent (preferably 1½%) voltage drop.

Where wire larger than No. 10 is required to eliminate excessive voltage drop on branch circuits, split the circuits, or move the panel board closer to the load center.

Length of Run is the one-way distance from source of supply to panel or from panel to outlet. The length of wire required between these points is double this distance for 2-wire circuits and three times the distance for 3-wire circuits.

These two articles were prepared under the guidance of Alvin L. Powell, president of the Illuminating Engineering Society, as consultant, by The Technical Editor of AMERICAN ARCHITECT. Data have been drawn from many sources, particularly the manuals and handbooks of leading manufacturers of Mazda lamps and modern lighting equipment

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